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U. S. DEPARTMENT OF AGRICULTURE,

DIVISION OF ENTOMOLOGY.

INSECT ENEMIES OF THE SPRUCE IN THE NORTHEAST.

A POPULAR ACCOUNT OF RESULTS OF SPECIAL INVESTIGATIONS, WITH RECOMMENDATIONS FOR PREVENTING LOSSES.

PREPARED UNDER THE DIRECTION OF THE ENTOMOLOGIST

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., July 1, 1901.

SIR: I transmit herewith the manuscript of a report by Dr. A. D. Hopkins, entomologist of the West Virginia Agricultural Experiment Station, on a trip taken in the summer of 1900, under the auspices of this Division, to the spruce-growing region in New England, for the purpose of investigating damage done by insects. The attention of the Department was called to a serious trouble affecting the spruce trees, in March, 1900, and Dr. Hopkins was chosen for the investigation for the reason that he has studied forest insects for many years and is generally known as the leading forest entomologist of the country. His report indicates that he was not only able to determine the cause of the difficulty, but to suggest practical measures of relief. I recommend that it be published as Bulletin No. 28, new series, of the Division of Entomology.

Respectfully,

L. O. HOWARD,
Entomologist.

Hon. JAMES WILSON,
Secretary of Agriculture.

PREFACE.

OBJECTS.

The primary objects of the investigations were (1) to determine the cause, or causes, of a prevailing unhealthy condition of the spruce in certain sections of the forests of Maine, New Hampshire, and Vermont, and to study the prevailing influences found to be favorable or unfavorable to the continuance or spread of the trouble; and (2) to determine, if possible, some practical method by which the owners of the timber could prevent or mitigate the great losses of valuable timber from this cause.

It is aimed in this report to give a popular account of the investigations and the principal results, with recommendations of such methods of prevention or control as seem practical.

The details of a technical nature, relating to results of more interest to the entomological student or investigator, will be reserved for a special report on this phase of the subject. It is hoped that this popular discussion will be of interest and value to the student and investigator of economic forestry problems, as well as to the practical forester and lumberman.

ACKNOWLEDGMENTS.

Before proceeding further I wish to express my acknowledgments to all those who have in any way given encouragement and assistance in this work, among whom the following deserve special mention: The executive committee of the regents of the West Virginia University and the director of the experiment station, for the necessary leave of absence; the Berlin Mills Company, through its president, Mr. W. W. Brown, and vice-president, H. J. Brown, for furnishing transportation and guide from Colebrook, N. H., across the State to the steamboat landing on the Magalloway River in Maine, and with guides and other facilities during my stay in the spruce woods of the Androscoggin drainage north of the Rangeley Lakes; to the Parmacheenee Club, through its vice-president, Mr. Henry P. Wells, and manager, Mr. J. A. Dunning, for accommodations at Camp Caribou and use of the Forks, Moosebog, Barkers Lake, and Lower Black camps, together with other favors extended; and finally to Mr. Austin Cary, who, as expert forester to the Berlin Mills Company, rendered most valuable service through his special knowledge of the Maine woods and the conditions in different sections most desirable to visit for investigation.

A. D. HOPKINS.

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OUTLINE OF TRIP.

On May 22, 1900, I arrived at Brunswick, Me., where I learned that Mr. Austin Cary, of that place, had gone with a surveying party to near the head of the Androscoggin River, and that, owing to floods and log jams on the upper streams, some trouble would be experienced in getting through to where he was located. This necessitated a delay of two days, but in the meantime arrangements were made by Mr. H. J. Brown, of the Berlin Mills Company, for transportation and guides from the railroad at Colebrook, N. H., until we found Mr. Cary.

May 24 I left Portland going northwest through New Hampshire via the White Mountain Notch to Colebrook. Here I was met by two guides sent over from Erral with instructions from the Berlin Mills Company, and on May 25 we left Colebrook, going up the Mohawk River valley and through the Dixville Notch near its source, thence down Clear Stream to Erral on the Androscoggin. Here we encountered the floods and log jams which prevented further progress by wagon, and the remaining distance to the Brown farm in Maine was traversed on foot and by canoe.

May 26, after spending a few hours in the woods studying insect enemies of the spruce, larch, and fir, we went on up the Magalloway River about 15 miles to the Camp in the Meadows where we were met by Mr. Cary. The next morning we proceeded farther up the river to the Forks Camp near the mouth of the Little Magalloway. This brought us into the heart of the northwestern Maine woods and within a few miles of one of the localities in which the spruce were dying.

Up to this time the route from Portland through New Hampshire and a small part of Vermont to Colebrook, thence across northern New Hampshire and up the Magalloway in northwestern Maine, led through a region presenting many and varied features of New England forest conditions, and gave a good opportunity to note in a general way some of the influences which contribute to the multiplication of insect enemies of trees, as well as those which contribute to their decrease, or even the extermination of certain species which confine their attack to matured timber. No opportunity was had, however,

to make a detailed study of any of the problems presented or suggested by the prevailing conditions until we reached this place.

May 28 we entered the undisturbed spruce forest in the vicinity of Wight's loggers' camps on Twin Brook, where the conditions were found to be especially favorable for commencing the investigation of a trouble which for forty or fifty years has attracted so much attention and caused the loss of vast quantities of spruce timber in northern New England and in New Brunswick.

After spending two days here in a thorough examination of a large number of infested living, dying, and dead trees, which bore every evidence of having been killed by insects, we extended our investigations further into the forest and across the divide to the Cupsuptic River drainage, and thence across to Lincoln Pond, where extensive summer cutting and peeling of the timber had been carried on. The examination of a great many dying and dead trees, together with a study of the conditions in the cuttings, left little doubt as to the primary cause of the prevailing trouble. Indeed, sufficient evidence was found to enable me to suggest to Mr. Cary a possible remedy, in providing girdled trees to attract the destructive insects, thus concentrating their breeding operations in sections of the forest where, by the ordinary logging operations, the entrapped enemy would be transported to the streams and thus destroyed.

The following day we returned to Wight's Camps, and thence went across to Black Cat Brook, Parmacheenee Lake, and Camp Caribou. Three days were spent in the vicinity of this camp, and on June 4 we proceeded to the Little Magalloway, and up this stream to Hamel's Camp. Thence the next day we went to near its source and the summit of Rump Mountain. This route, leading as it did through an extensive burned-over area, recent cuttings, and undisturbed forest, where much dying and dead timber was found, gave an excellent opportunity for the successful prosecution of the investigations. The observations we were enabled to make from the summit of the mountain were also of especial interest and importance.

We returned to Camp Caribou June 7, where I was joined by Mr. Henry Carter, who had instructions from Mr. Cary to accompany me on an exploration in the heart of the wilderness north of Camp Caribou. We started on June 8, going to Little Boys' Falls on the Magalloway; thence by trail and canoe to and above Moose Bog Camp, and thence by trail via the Game Keeper's Camp to Barkers Lake, which is located near the Canadian line and forms the principal source of the Magalloway. From here we returned by trail to Lower Black Camp and thence to Camp Caribou, where we arrived in the evening of June 11.

This trip enabled me to gather much valuable information relating to the distribution of the trouble; the condition of the timber that had been dead five to twenty years; and the relations of old cuttings,

blow-downs, and other prevailing features which had a direct bearing on the problem under investigation.

Mr. Cary joined me again at Camp Caribou, and June 13 we proceeded by the old Danforth trail to the Cupsuptic River, and thence to the Stonehouse on the lake near its mouth. From here we proceeded up the Kennebago River and devoted several days to the exploration of the great spruce region at the sources of this and Dead River. This also included a climb to the summit of Boil Mountain where, as from Rump Mountain, an excellent view was had of the prevailing conditions as to dead and living timber over a vast extent of forest.

Between Kennebago Lake and Beaver Pond we had a good opportunity to study the conditions in the historic blow-downs of 1871 and 1883, which were followed by great invasions of spruce-destroying insects.

We returned to the Cupsuptic June 17, and next day I returned to Brunswick and Portland. After making some investigations on Peak Island and in the vicinity of Portland, and reporting to the Berlin Mills Company some features of the results of my investigations in sections of the Androscoggin region in which they were specially interested, I returned home, where I arrived June 29.

The specimens of insects and their work collected on this trip numbered something over 1,700, including 44 species from the Red Spruce, six from the White, and nine from the Black.

THE ANDROSCOGGIN REGION AND ITS SPRUCE FORESTS.

The Androscoggin drainage north of the Rangeley Lakes and west of the headwaters of the Dead River of the Kennebec, in which the investigations were conducted, is one of great interest, and since the varied conditions prevailing there have a direct bearing on the problems to be discussed further on in this report, it seems fitting and proper that some space should be devoted to its discussion. In this I can do no better than to quote from the writings of Mr. Cary, than whom there is probably no better authority. Indeed, after having gone over the territory with him I learned to have much confidence in his ability as a practical expert forester and a careful and accurate observer of forest conditions.[1]

* * * These townships [Grafton, Andover, North Surplus, Letters D and E, and No. 6] that I have referred to form a barrier separating the upper from the lower course of the Androscoggin. To the south is the lower river, flowing approximately east for 50 miles, catching streams from both sides of its course. To the north of that barrier lies the Rangeley Lakes system, again with its axis east and west and about 30 miles in length. The lakes, therefore, situated as they are close under this mountain barrier, receive only trifling tributaries from the south. Their volume is chiefly maintained from the country to the north, which

[1] Paper by Mr. Austin Cary, in Third Annual Report of the Forest Commissioner of Maine, pp. 127, 128, 1896.

drains into them by three considerable streams—the Magalloway, the Cupsuptic, and the Kennebago. The outlet of the system is at the west where the river forces a way for itself close under the eastern face of the White Mountains. At the east, on the other hand, the upper lakes are closely approached on the high but elevated land by the headwaters of the Dead and Sandy rivers, which run into the Kennebec.

Now, as the Rangeley Lakes, with the exception of Umbagog, are about 1,400 feet above the sea, while the country about is, much of it, considerably higher, this Upper Androscoggin country is more elevated than any other area of equal size within the limits of the State.

Here on the headwaters of the Androscoggin is the chosen home of the spruce. Continuous with the high land of northern New Hampshire, a part of the great White Mountain plateau, this region in its elevation, its uneven topography, and its climate seems to afford that combination of conditions which ministers to the perfect development of the spruce. The timber of the Appalachian Mountains farther south is not known to the writer. It is a fact, however, that no other part of Maine ever had any such spruce stand, and probably no portion of New York or New England as is found from here across northern New Hampshire. Only patches of timber elsewhere stand as thick as does the country here. Much of the timber too is of the finest quality and size. * * *

Returning again to Parkertown, let me present some figures that will be used in a further discussion of the problems arising in connection with the management of the Androscoggin land. First is the detailed statement of the trees standing on a sample acre that, fairly representative of the country in its stand of merchantable spruce timber, was thought to be appropriately such also in respect to the proportion of hard and soft wood in large and small trees. Note particularly the number of large spruce trees as compared with those from 6 to 12 inches in diameter. Their relation is no chance or insignificant matter. Much study has shown it to be characteristic of typical Androscoggin spruce land, while from it are drawn hereafter important practical conclusions:

Trees standing on an acre of uncut land in Township 5, Range 3, Oxford County.

Spruce.					Other species.					
Diameter.	Number.	Height.	Volume.	Estimated scale.	Diameter.	Yellow Birch.	Beech.	Maple.	Fir.	Estimated volume.	Estimated scale.
Inches.		*Feet.*	*Cu. ft.*	*Ft. B. M.*	*Inches.*					*Cu. ft.*	*Ft. B. M.*
Over 18[1]	14	70–90	1,000	3,500	Over 18	11	----	1	----	1,000	----------
15–18[1]	14	70–80	600	2,000	14–18	6	----	4	----	400	----------
12–14	9	60–75	210	840	12–14	2	2	6	----	200	----------
10 and 11[1]	8	50–65	135	502	10 and 11	4	3	8	1	300	----------
8 and 9	18	40–50	170	510	8 and 9	3	3	13	3	200	----------
6 and 7	6	35–45	35	----------	6 and 7	3	2	3	1	50	----------
3–6	32	40	60	----------	3–6	8	10	4	44	130	----------
Under 3	90	----------	10	----------	Under 3	4	29	1	165	20	----------
Total	191	----------	2,220	7,352	Total	41	49	40	214	2,300	4,000

[1] One worthless tree in each class.

* * * In the estimated scale put upon the sample acre—about 7,400 feet—5,500, or three-quarters of the whole, was in the shape of trees over 14 inches in diameter 4 feet from the ground. That is a fact to be distinctly marked. Three-quarters of the total spruce in the natural stand of the country is mature—ready in the natural course of things to be cut. This is not merely the lumberman's interest. It is the State's interest. In timber like this, growth is balanced

by decay. Dead trees stand scattered throughout it. Upon this very acre there was one. Several more were dying or imperfect, while doubtless several of the 28 full-grown trees scored are every year decreasing in value. These large, old trees, too, cumber the ground. Producing little themselves they yet, by their shading, keep down the young growth, which could make good use of the room. No one can dispute the lumberman's right or interest in regard to these trees.

* * * The Androscoggin drainage, from the spruce point of view, is the best worthy of study of all the rivers of the State. It is also the one, in my judgment, on which a conservative forest policy is likely to go first into effect.

In a letter to Mr. Cary, Mr. J. A. Pike estimates that the spruce then (December, 1895) standing in the Androscoggin basin, at and above Berlin, Me., was 3,000,000,000 feet. He says:

This estimate is based largely on personal examination and entirely upon personal knowledge of the territory and the character of the growth, and after consulting notes and memoranda extending over a period of more than twenty years.

Mr. Cary again refers to the spruce of Maine in a paper read before the Boston Society of Civil Engineers, May 10, 1899,[1] as follows:

It seems probable, then, that 25,000,000,000 feet, board measure, may approximate the amount of spruce woods standing in the State. The total lumber cut in the State in 1896 was something over 600,000,000 feet. Of this, probably 500,000,000 feet was spruce. About two-fifths of this went to the paper and pulp mills.

Six hundred million feet is equivalent to 30 feet per acre on the gross area of the State. Five hundred million feet may be 50 feet per acre on the area of what we might call spruce-producing land. These figures are within the amounts which such stands as have been made attached to ordinary cut-over land as its yearly growth. Certainly they are small in comparison to what we know that scientific forestry has produced elsewhere.

The general inference to be drawn from these facts is not a discouraging one. Our resources are still great, and we may feel justified in using them freely.

At present the botanists recognize three distinct species of spruce from New England, the Red (*Picea rubens*), the White (*Picea canadensis*), and the Black (*Picea montana*) (Plate I), all of which were noted by the writer and their insect enemies studied.

One of these, the Red Spruce, on account of its size, great value, and prevalence throughout the spruce area, is recognized commercially as "The Spruce," while the others, from an economic standpoint, are of secondary or minor importance.

DEAD AND DYING SPRUCE.

The prevailing condition which attracts especial attention in the upper Androscoggin, is the large amount of dead spruce. It stands in clumps of a few trees to several hundred, and as individuals scattered through the forest, or left in the cuttings. In some places the old-felled trunks and tops make travel through the woods exceedingly difficult.

[1] Jour. Assoc. Eng. Soc., Vol. XXIII, No. 2, Aug., 1899, p. 5.

While a large amount of dead spruce was observed throughout the area traversed, that which was then dying, or had died within the past one to four or five years, is limited to well-defined areas of greater or less extent, in different sections, but always involving the best stands and largest timber.

The dead spruce is not confined to any particular condition of soil, exposure, or altitude, but is found under all conditions, from bogs to high, exposed, rocky slopes, or whenever the trees attain a diameter of over 12 inches.

SOME CHARACTERISTICS OF THE DYING AND DEAD SPRUCE.

When the trees commence to die, the first indication in their general appearance is a pale tint of the leaves on the upper branches and tops. These soon fall, even before they lose their green color. When the trees are in this stage of decline, the wind or a slight jar, as with an ax, will cause a shower of the needles to fall, and the ground will be covered with them. After the leaves have fallen, the dead twigs present a reddish appearance, rendering them quite distinct and easily recognized from a distance, when viewed from an elevated point. They gradually assume a light-gray appearance, followed by a darker gray; then, a few years later—the actual time not yet determined—the twigs begin to fall; later the branches, and still later the tops break off. Finally, after many years—ten to twenty or more, depending on the soundness of the base and roots—the decaying trunk will topple over, and contribute to the food supply of the young generation of trees, which have sprung up to utilize the sunlight thus made available.

Trees with diseased roots usually fall before they have lost their small branches, and the wood probably decays far more rapidly than in those with sound roots.

The only way the declining, dying, and recently dead trees can be recognized from the trail, or in going through the woods, when the tops come between the observer and the sky, is by the fine dust in the outer bark and moss near the base, the pitch tubes on the bark from near the base up to 10 or 20 feet, the falling or fallen leaves, or the work of woodpeckers. The removal of the outer bark by the birds in search of insects makes the reddish inner bark conspicuous, even on living trees, when they show no other indication of decline. Indeed, the trees on which the birds have been at work stand out distinct, and can be seen for a long distance in the woods.

CAUSES OF DECAY AND DEATH.

There are two causes of decay and death, one or both of which affected each of the many hundreds of trees examined: (1) The work of an insect in the bark on the middle trunk, causing the death of the

tree; (2) the presence of fungi in the bark and wood. The latter has been investigated by Dr. Herman von Schrenk, for the Division of Vegetable Physiology and Pathology, and his report has appeared in a bulletin of that Division. Therefore, only such reference will be made to these diseased conditions as has a direct or interrelated bearing on the insect problem, and methods of preventing losses from their combined attack.

RELATION OF INSECTS TO THE TROUBLE.

With very few exceptions[1] all of the great number of affected trees examined, which were in all stages, from living to old dead ones, throughout the area covered by the trip, showed evidence of depredation by insects; and in nearly every case quite conclusive evidence was found that one species, a bark-mining beetle, had been or was then associated with the primary cause of these unhealthy conditions and death. This evidence consisted in the healed-over burrows in the living bark of healthy, vigorous trees; in broods of this insect which had developed in the bark of living trees during the summer of 1899, the trees yet living in May and June, 1900; in the hundreds of dying and dead trees, with vast numbers of all stages, from young larvæ to adults, of this insect under the bark, where they bred the previous summer and fall; and finally its characteristic galleries in the bark, or on the surface of the wood of old dead trees which had been dead from ten to twenty years, while the logs, stumps, and tops in cuttings showed little evidence of its attacks.

In addition to this common and primary enemy of the spruce, many other species of bark beetles, flat-headed and round-headed bark and wood borers, occurred in the dying and dead trees, some following closely the first attack by the primary enemy, others coming later, and still others in succession until the last vestige of the bark and wood is converted back to earth.

THE SPRUCE-DESTROYING BEETLE.

The observations of the writer lead him to conclude that of all the insect enemies of the spruce, this beetle must take first place as the most destructive. It is the leader in the attack, while the others,

[1] In all forests, and especially those in undisturbed or natural condition, a certain percentage of trees seem to die naturally. While there is no such thing, perhaps, as a natural death of a tree, there are those which, in their struggle for existence with their many younger and more vigorous competitors, become weakened in their vitality and thus are more susceptible to the attack of their numerous enemies among insects and fungi, and also to the injurious effects of unfavorable climatic conditions, which, combined, cause them to die. Trees perishing in this manner, however, occur as isolated individuals, scattered throughout the forest, and seldom, if ever, in clumps.

found in the bark and wood, are followers, allies, dependents, or natural enemies of one or more of the bark and wood miners.

DESCRIPTION OF THE DESTROYER.[1]

This insect belongs to the order Coleoptera, the true beetles, which are most distinguished in a general way by their hard wing covers. It belongs to the family of beetles known as Scolytidæ and to the genus Dendroctonus. Up to the present time it has, together with several other distinct but closely allied forms, been recognized by entomologists under the specific name *rufipennis*, a name that was applied by the English entomologist, William Kirby, to a species described by him in 1835 from specimens collected on a journey from New York State to the shores of Hudson Bay. It has been determined, however, by comparison with the original specimens now in the British Museum collections,[2] that the spruce-destroying beetle is quite distinct, and I have applied to it the name *Dendroctonus piceaperda*, meaning spruce destroyer.

The adult (Pl. II, figs. 1, 2) varies in length from three-sixteenths to five-sixteenths inch (4.7 to 6 mm.), and in width from one-sixteenth to nearly two-sixteenths inch (1.9 to 2.6 mm.). It also varies in color from light yellowish in the younger specimens to dark reddish-brown and, in some mature individuals, nearly black. It will be more readily recognized by the general observer from its common occurrence in the bark of dying and recently dead spruce trees; also by the character of its work, described and illustrated further on.

The egg is a small pearly white object, scarcely to be distinguished, if at all, from those of other bark beetles of the same size.

The larva is, upon hatching from the egg, a minute, white, legless grub (Pl. II, fig. 4), which feeds on the inner bark and increases in size until it has attained a diameter equal to that of the adult and a length somewhat greater. It may be distinguished from any other similar larva as yet found in the Eastern spruce by a dark yellowish-brown space on the upper surface of each of the last two abdominal segments (Pl. II, fig. 4*a*).

The pupa (Pl. II, fig. 3) is nearly white, of the same size and somewhat the same form as the adult, but without free legs and wings, and is found in oblong cavities in the bark of the trees where the broods develop.

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[1] Detailed technical descriptions will appear in a special paper to be published later.

[2] Specimens of the Dendroctonus collected from spruce in Maine, together with specimens of another species from Hudson Bay and Lake Superior regions, were sent to the British Museum and were compared, by Mr. Charles O. Waterhouse, with Kirby's types. He found that the one from Lake Superior agreed with the labeled specimen, the one from Hudson Bay agreed with another, and the specimens from Maine were different from any in the type series.

LIFE HISTORY OF THE BEETLE.

The time of year when the investigation was made was especially favorable for studying the hibernating habits of this insect, and enabled the writer to commence a study of its life history with the later part to the close of its dormant or inactive period.

HOW IT PASSES THE FALL, WINTER, AND SPRING.

The fall, winter, and spring, and part of the first summer month are passed in all stages of the larva, from quite small to full grown, as well as in the adult stage, developed the preceding summer or fall.

So far as could be determined by the writer, the eggs deposited too late in the fall to hatch before cold weather sets in, the pupæ that develop too late to change to the adult, and some of the very young and tender adults, do not survive through the winter.

The adults hibernate in the bark and usually but a short distance from where they were located when they transformed from the pupæ or where the winter found them in their primary galleries. The larvæ are found in their mines, where they ceased feeding in the fall. The very young to nearly matured larvæ are often found in living bark, while the developed broods of the adults are nearly always in bark which has recently died. In some trees many dead adults were found, which, owing to some unfavorable condition, probably within the bark itself, had died or been killed by the winter freezing, while in the greater number of infested trees all stages but the eggs and pupæ, had not been injured in the least; indeed, they seemed to be in as perfect health as when they ceased activity in the fall.

WHEN ACTIVITY COMMENCES IN THE SPRING.

When the first individuals were seen on May 28, near north latitude 45°, and at an altitude of about 2,000 feet, all of the hibernating stages were inactive. This condition continued until about June 4, when warmer weather set in and indications of activity were noted. On June 5, at Hammel's Camp, on the Little Magalloway, the matured larvæ were found to be almost ready to change to the pupæ. The next day, in the same locality, numerous pupæ were observed, which had just transformed from the larval stage. From that day on to June 17 the pupæ were commonly met with and the young larvæ were apparently feeding. Toward the 13th the adults showed evidence of uneasiness, as if preparing to emerge, and the first one of the season was observed excavating an entrance in the living bark of a healthy spruce. I was not positive, however, that it had not commenced this excavation last fall and remained in it over winter. Indeed none were observed flying then or up to the time the last observations were

made just before my leaving that region on June 17. It is therefore possible that some individuals pass the dormant period in the outer bark, where they had commenced to excavate entrances in the fall.

THE SUMMER PERIOD.

In the course of Mr. Cary's observations in connection with the girdling experiments some important information relating to the life history of this beetle was noted by him. According to his notes the beetles commenced to emerge about the middle of June. Galleries had been excavated in some of the girdled trees and eggs were deposited by June 19. The first larvæ were noticed on July 28 to 31. Pupæ were common on September 1, with a few recently developed beetles, and on October 4 many of the beetles had fully matured, but none had emerged. It is therefore probable that the beetles will not emerge and attack other trees before the following summer, although a few early developed beetles may emerge in October and enter the outer bark of living trees.

Mr. Cary's observations furnish quite conclusive evidence that in northwestern Maine there is but one brood in a season, even from the hibernating adults, and that the period of development from the egg to the adult is about seventy to seventy-five days—from the middle of June to the last of August.

SUMMARY OF LIFE HISTORY.

These observations would also indicate that activity ceases in the fall by about the middle of October, when all stages of the insect may occur in the bark of infested trees where they, with the probable exceptions of the eggs and pupæ, remain until the first week in June. Activity then commences, the mature larvæ change to pupæ, and by the middle of June those that pass the winter in the adult stage emerge and commence to excavate galleries and deposit eggs. The adults from the hibernating larvæ of different stages, develop and continue to emerge possibly until the last of August. Therefore the eggs deposited by the late-developing beetles produce larvæ which do not complete their development until July or August of the next year. Thus, the period of development may vary from about seventy days to about twelve months, but all broods from eggs to matured and emerging adults remain in the bark about twelve months, of which they are dormant about seven and one-half and active four and one-half.

The following diagram will indicate the probable normal rate of development from the different hibernating stages:

EXPLANATION OF DIAGRAM.

The accompanying diagram (fig. 1) illustrates the dormant and active periods and the rate of development of *Dendroctonus piceaperda*. The symbols at the left represent the different stages of the insect in the bark of infested trees when activity ceases, about the middle of October: (●) represents the mature, immature, and very young adults; (⊙) represents the pupæ; (◦ ○ O) represent three stages of the larvæ, and (•) the eggs.

Commencing with the mature adults, in the upper line, the normal, or average, dormant and active periods, and the periods of development are represented as follows: The dormant period of two hundred and thirty-two days ends about the 5th of June; in about ten days more the adults commence to emerge; in twenty days eggs are deposited; in thirty days larvæ commence to appear; in sixty days the larvæ are matured; in sixty-five days pupæ commence to develop; and in eighty days from the time activity commences the first adults develop; they probably continue

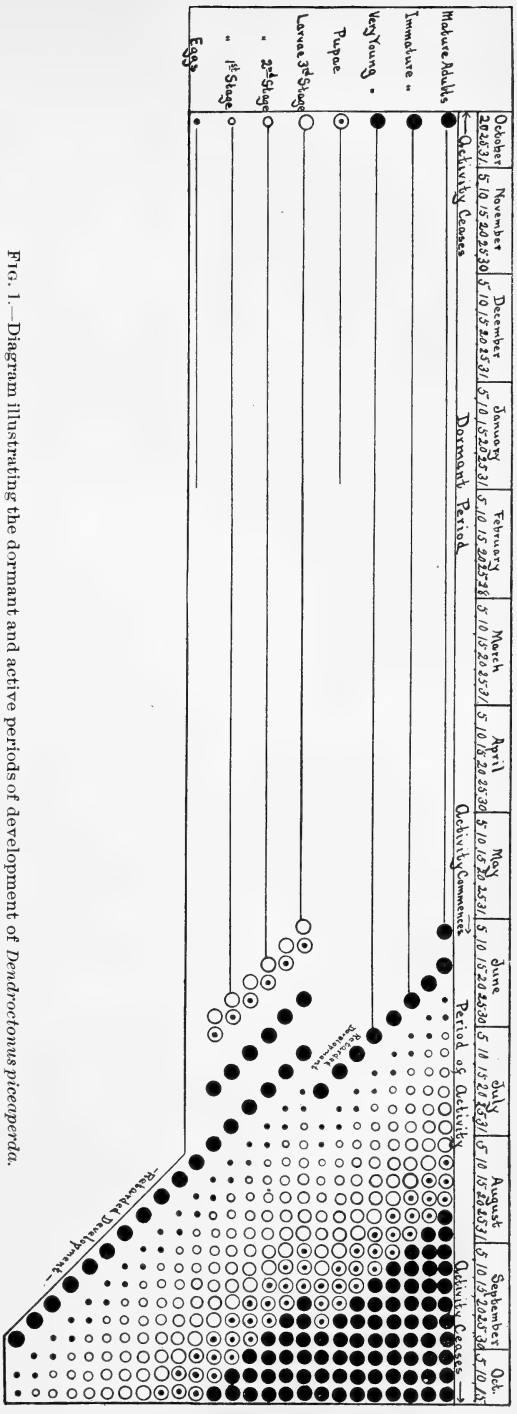

FIG. 1.—Diagram illustrating the dormant and active periods of development of *Dendroctonus piceaperda*.

to develop until toward the last of September, but they remain in the bark until activity ceases. The hibernating, immatured, and very young adults appear ten to twenty days later than the fully matured ones; they continue to emerge and deposit eggs until about the last of July.

The few pupæ present when activity ceases evidently perish by the last of January, as do also the eggs.

The three stages of hibernating larvæ develop to adults after activity commences in the same ratio as the hibernating adults, but owing to retarded development some of them probably do not attain the adult stage until late in September. Thus adults would be coming out during the entire period of activity, which accounts for the existence of all stages when activity ceases in the fall.

SPECIAL FEATURES OF THE BEETLE'S WORK.

KINDS OF TREES ATTACKED.

So far as known this beetle attacks only the spruce, and the most striking and important feature is its habit of attacking only the larger trees. It is rarely found in trees below 10 inches in diameter breast-high, but in all infested areas is exceedingly common in those over 18 inches at the same height. It also appears to have a decided preference for standing trees, although some evidence was found that it will breed in wind-felled trees and rarely in stumps and logs in cuttings.

HOW AND WHEN THE ATTACK IS MADE.

A study of the living trees which had recovered from a slight attack, as well as those that were infested by different stages of the insect, indicated quite clearly that the first entrances are made in the bark of the healthy tree at a point from 6 to 10 feet from the base, and that trees which are weakened in vitality from disease or other causes may be attacked from near the base to near the first large branches.

The fact that as a rule the infested trees are found in clumps or confined to definite areas of greater or less extent would indicate a social habit, and that the individuals may migrate in swarms from an old to a new locality and settle without any special choice except as to size or number of trees. Thus they invade the trees on all sides, and usually in such numbers as to prevent recovery from the first attack. As soon as the trees commence to decline they are invaded by other bark-mining beetles and grubs, which aid in their final death and decay.

ITS WORK IN AND BENEATH THE BARK.

The entrance and the primary gallery.—This is started, probably by the male, hidden in a crevice or beneath a flake of bark, and, if in a living tree, is gradually and obliquely extended upward or to one side through the inner bark. The male is then joined by a female,

and together they excavate a broad primary or egg gallery (Pl. III) up through the inner bark, often grooving the surface of the wood, for a distance of from 2 to 9 inches. Along the sides of this gallery, which is usually about three times as broad as the beetle, the eggs are placed singly in small cavities or in groups along a notched groove. The eggs are then protected by a mass of borings cemented with gum, which are closely packed, filling up the broad egg gallery, with the exception of a small central burrow which is left or is subsequently excavated through the middle of its entire length. The original entrance is first packed, then an opening to the outside is made in the roof of the gallery a few inches from the entrance, another section is excavated and packed and another hole is made through the roof, and so on until the gallery is completed. After all is finished the adults make one or two irregular lateral branches at the farther end, apparently for an abiding place until they die.

The gum flowing into the wound made by the beetle when it is excavating the entrance is pushed out and a hole kept open through it, thus forming what is known as pitch tubes, which are so conspicuous on the bark of recently attacked trees. After the vitality of a tree is weakened by numerous wounds and an excessive flow of resin, the entrances subsequently made are not marked by pitch tubes; or if a tree is decidedly weakened from other causes before it is attacked, pitch tubes will not be formed.

When numerous beetles are boring into the outer bark the dry dust falls down and lodges in the flakes of bark and the moss on the tree, so that a freshly attacked tree may be identified from its presence.

The secondary or larval mines.—When the eggs hatch, the minute white grubs or larvæ eat their way into the soft inner bark, which by this time has commenced to die and is in the best condition for their food supply. When the eggs are placed in separate cavities each larva makes a separate mine, but when they are massed along the sides, or placed close together, they work side by side and consume all of the inner layer of bark until they have progressed some distance, when they begin to separate and each larva makes an independent mine. (Pl. IV.) While the individual burrow may cross and recross those of its neighbors, it preserves a course of its own and increases in width as its occupant increases in size until the larva attains its full size and ceases to feed. It then excavates a cavity either in the bark next to the wood or next to the outer dry bark, where in due time it changes to the pupa. Here it remains in a semidormant condition until the legs, wing covers, and other parts develop. It then sheds its outer skin and becomes an adult winged beetle, soft and yellow at first but gradually hardening and becoming darker. In due time the mature beetle bores its way out to the surface and emerges to fly about in search of a tree in which to excavate galleries for another brood.

THE DISTINCTIVE, VISIBLE EVIDENCES OF THE SPRUCE DESTROYER'S WORK.

The characteristic features which are of considerable importance to the forester and lumberman in recognizing the presence and work of this beetle and its broods may be mentioned, as follows:

PITCH TUBES.

The tubes or balls of pitch, which are pushed out from the wounds made by the beetles when excavating an entrance for their galleries constitute one of the first and most characteristic indications of the presence of this pest in the living spruce. If upon cutting into the bark around one of these pitch tubes, injuries are found like those just described (Pls. III and IV), one may be quite certain that they are the work of the true spruce destroyer.

APPEARANCE OF THE LEAVES.

The leaves of a dying tree infested by this insect change from the dark healthy to a pale or grayish green, and soon fall, thus indicating the presence of this pest. And if the bark of an infested tree is examined at this stage, fully developed larvæ and even fully developed broods of the adult may usually be found.

APPEARANCE OF THE TWIGS.

After the leaves have fallen the infested trees present, by their reddish appearance, a far more striking contrast with the healthy foliage, and are thus easily recognized at a considerable distance. If the bark is examined at this stage the broods of the spruce destroyer will be found nearly or quite fully developed, or they may have emerged.

APPEARANCE OF THE BARK AND WOOD.

Since it is absolutely necessary for the beetle to deposit its eggs in living or partly living bark, in order for the young larvæ to have the proper conditions for their future development, there is seldom more than one set of broods developed in the same tree, unless, as is sometimes the case, but one side of the tree is attacked one year and the other side the next, when two sets of broods might develop in the same tree. As a rule, all have emerged before the twigs begin to change from their fresh reddish appearance after the leaves have fallen. After this stage is passed the previous presence of the beetle is indicated only by the evidences of its work in and beneath the bark and on the surface of the wood, which may be readily recognized from the illustrations and descriptions given. (Pl. V.) The pitch tubes sometimes remain on the bark several years after the tree dies, and as long as there is any bark on the middle portion of the trunk this

evidence will enable anyone who has given the subject some attention to determine that such trees were attacked while living.

After all of the bark has fallen from the trunk of standing or felled trees, the characteristic grooves in the surface of the wood, made by the beetle when the primary galleries were excavated, are often quite conspicuous, even on trees that have been dead for fifteen to twenty years.

WOODPECKER WORK.

Another, and indeed one of the most conspicuous evidences of the presence of the spruce-destroying beetle, is found in the work of woodpeckers on the middle trunk of the dying and dead trees. Scarcely an infested tree escapes the bird, and the outer bark removed by them in their search for the insect gives such trees at first a red, and later a smooth, light-grayish appearance, which is very conspicuous. Even living trees infested by the insect can be recognized by this means at a greater distance in the woods than by any other of the conditions mentioned. It must be remembered, however, that all spruce trees showing the work of woodpeckers are not necessarily infested by the spruce destroyer. For, as in the case of trees which have been infested with other bark beetles, or the flat-headed and round-headed borers, the birds scale off the bark in the same or a similar manner. Examples, however, of trees dying from the work of these secondary enemies are rarely met with. Therefore the work of the woodpeckers, especially in the Maine woods, is quite reliable evidence of the presence of the spruce destroyer.

A COMMON FUNGUS ON THE BARK OF DEAD TREES.

Nearly all recently dead trees, and even some that are not yet dead but contain broods of the beetle, are found to have a small, yellow, globular fungus (Pl. VI) protruding either from the holes in the roof of the egg galleries or those made when the adults emerged from the bark. This fungus, which grows beneath the bark, pushes its way out to develop spores or fruiting parts.

These fungi are conspicuous objects, and they often occur by hundreds on the bark of the trees for two or three years after they have died and the beetles have emerged. The fact that the work of the spruce-destroying beetle seems to make the conditions more favorable for the introduction and subsequent growth of this fungus indicates that it is more closely associated with the work of this beetle than is any of the other bark and wood-infesting fungi of the spruce. It therefore serves as good external evidence that the dead trees on which it is found were killed by the beetle. It will, however, grow from the burrows made by other insects in the bark, or, as observed in one instance, from the burrows of wood-mining beetles, *Xyloterus bivittatus* Kirby, in wood from which the bark had been removed.

THE PRINCIPAL NATURAL ENEMIES OF THE SPRUCE-DESTROYING BEETLE.

Among a number of insect enemies of the different stages of the beetle at least two are worthy of special mention—one a true parasite, the other a predaceous enemy.

A PARASITIC INSECT.

The commonest parasite of the larvæ is a small four-winged wasp-like insect belonging to the order Hymenoptera, family Braconidæ, genus Bracon, and species *simplex* Cress. This insect appears on the wing about the time or a little before the beetles emerge from the bark in the early summer and commences to deposit its eggs by means of a long, stinglike ovipositor which it inserts in and through the bark infested by different stages of the larvæ, on or by which it places its eggs. The minute maggot hatching from this egg attaches itself to the side of its victim and sucks out and feeds upon the liquids of its body. The beetle larva soon dies, and after the parasite larva has attained its full growth as such it incases itself in a thin, paperlike cocoon (Pl. VII) in which it goes through its transformation to the adult. It then emerges and in a like manner continues its good work in destroying the destroyer. While cocoons of this parasite were frequently met with in the larval mines of the beetle in nearly every locality where infested trees were examined, it was nowhere common enough to be of any special service except near the sources of the Kennebago and Dead rivers. Here it was quite common and had killed a great many larvæ. In one tree as many as six cocoons were found in a piece of bark 2 inches square. It is only in the thinnest bark, however, that this parasite can do much good in destroying the larvæ, and since the beetles usually select only the old trees with thick bark, and do not infest the tops where the bark is thinner, it would appear that this parasite can not, alone, do a great amount of good. In connection with other beneficial factors, however, it contributes its share to reducing the numbers of the destructive beetles, and thus is an important factor.

A PREDACEOUS BEETLE.

Different stages of a beetle closely related to the one that was introduced by the writer into the spruce and pine forests of West Virginia from Germany in 1892–93, to prey upon the destructive pine bark beetles, were frequently met with when examining infested trees, but were not especially common, except in the same section where the parasite was common.

This beetle belongs to the order Coleoptera, family Cleridæ, genus Thanasimus, and species *nubilus*. It is antlike in appearance, especially when running about on the bark. The adult is about one-fourth

of an inch long and one-sixteenth broad. Its head is black; middle portion of the body red; the wing covers are marked with zigzag black and gray transverse bands.

The adult emerges from the bark of the infested tree somewhat earlier than the spruce-destroying beetle, and remains hidden under the flakes of bark or in the moss until the adults of the spruce beetle commence to emerge. It then pounces upon the beetles as they emerge and devours them. When those that escape fly away to settle on the living trees, this little clerid enemy evidently does as other clerid species do. It accompanies them and continues its work until the escaping beetles have burrowed into the bark. The adult clerid does not follow them into their galleries, but does the next best thing—deposits its eggs at the entrances, so that the active reddish worms hatching therefrom can find their way into the bark and feed on the bark-beetle larvæ.

When the clerid larvæ attain their full size they retire from the larval mines they have depopulated and enter the central tube in the primary or egg gallery made by the spruce beetle. This, in fact, seems to be a favorite place for them to make their pupa cases in which to transform to the pupa and adult. Some of the larvæ evidently make pupa cases in the outer bark, as is the common habit of nearly all the other species known to the writer; but it would seem that by far the greater number pupate within the central tube in the broad egg galleries excavated by the bark beetle.

This clerid is, without doubt, a very efficient enemy of the bark beetle, especially when it occurs in such numbers as observed in the spruce near the head of the Kennebago River.

A parasite was reared from a pupa case of this clerid which is very closely allied to a parasite of the imported clerid found by the writer in Germany.

BIRDS AS ENEMIES OF THE BEETLE.

As has already been stated, woodpeckers are the most important enemies of the bark beetle, and appear to be of inestimable value to the spruce-timber interests of the Northeast. Indeed, I feel confident that in the many hundreds of infested trees examined at least one-half of the beetles and their young had been destroyed by the birds, and in many cases it was evident that even a greater proportion had perished from this cause alone.

Estimating 100 beetles to the square foot of bark in the average infested tree, and an average of 60 square feet of infested bark, it is possible for each tree to yield an average of 6,000 individuals; one hundred trees, 600,000, and so on. It is therefore plain that, if one-half or two-thirds of this number are destroyed by the birds and other enemies, the amount of timber the remainder can kill will be lessened. This is all the more apparent when it is remembered that it is only

when the beetles occur in great numbers that they can overcome the resistance of the living trees.

The following is a list of the common and scientific names of the woodpeckers of northern New England, kindly prepared for me by Dr. C. Hart Merriam, Chief of the Biological Survey, U. S. Department of Agriculture:

Hairy woodpecker	*Dryobates villosus.*
Downy woodpecker	*Dryobates pubescens medianus.*
Arctic three-toed woodpecker	*Picoides arcticus.*
Banded three-toed woodpecker	*Picoides americanus.*
Yellow-bellied woodpecker	*Sphyrapicus varius.*
Red-headed woodpecker	*Melanerpes erythrocephalus.*
Flicker	*Colaptes auratus luteus.*
Pileated woodpecker	*Ceophlœus pileatus abietorum.*

No positive evidence was obtained as to which one or more of these birds is to be credited with the larger part of the beneficial work, but, from such observations as were made in the woods and information given by Dr. Merriam, and through one of his correspondents, Mr. William Brewster, at Bethel, Me., it would appear that the Arctic three-toed and banded three-toed woodpeckers render by far the greatest service, and probably do their principal feeding during the winter on the species of insect now under consideration.

A FUNGOUS DISEASE OF THE BEETLE.

While quite a number of beetles and larvæ were found which had evidently perished from a fungous disease, the percentage dying from this cause was not sufficient to be of any perceptible benefit.

CLIMATIC CONDITIONS.

While very severe freezing, or a sudden change from cold to warm, or vice versa, may kill a great many of the pupæ, young beetles, and even the larvæ, except in a few cases but little evidence was found showing that these conditions had produced appreciable effects.

THE PRINCIPAL INSECT ALLIES OF THE SPRUCE-DESTROYING BEETLE.

Among the large number of different kinds of insects which come to the aid of the spruce-destroying beetle, or follow its attacks, there are at least two which are worthy of especial mention in this connection; one is the spruce Polygraphus,[1] or lesser spruce bark beetle, while the other is the spruce Tetropium.[2]

THE SPRUCE POLYGRAPHUS.

This is by far the commonest secondary enemy of the spruce throughout the spruce region of West Virginia, and was found to be exceedingly common in all of the sections visited in northwestern

[1] *Polygraphus rufipennis* Kirby. [2] *Tetropium cinnamopterum* Kirby.

Maine. It belongs to the same family of beetles as the true destroyer, but to an entirely different genus. The specific name, *rufipennis*, given to it by Kirby, is unfortunately the same as that he gave to the Dendroctonus described from the same region. This has caused much confusion in the writings of entomologists and others relating to the insect enemies of the spruce.

This species is enormously abundant in all injured and dying standing trees, and in the bark of the branches, tops, and stumps, in cuttings, windfalls, etc. (Pl. VIII, *e*, and Pl. IX.) Its abundance, together with its habit of infesting the tops of trees immediately after the middle portion of the trunk or base has been attacked by the spruce-destroying beetles, renders it one of the most efficient allies of the primary enemy.

The adult is a small black beetle about .08 of an inch long and .01 of an inch broad. It is easily distinguished from all other spruce bark beetles of similar size and form by the fact that each of its compound eyes is divided by a smooth narrow space. It passes the winter in all stages within the bark of spruce stumps, logs, and the tops of felled and standing trees.[1]

THE SPRUCE TETROPIUM.

This is the round-headed bark and wood-miner which was found to be so common in the spruce of West Virginia in 1891, where its work contributed to the rapid decay of the wood of dead trees.[2] It is very common in the spruce of Maine, where it was observed by the author in the stumps and logs of recently felled trees and toward the base of trees attacked by the spruce destroyer. Indeed, an attack by the latter is followed almost immediately by the Tetropium adult, which deposits its eggs in the outer bark from toward the middle of the trunk to the base. The young larvæ are capable of mining through the living bark (Pl. X) and continuing their work regardless of the sap and pitch. Therefore, this insect must be classed as one of the principal aids to the spruce beetle in not only causing the death of the trees, but in contributing to the rapid decay of the wood.

OTHER INSECTS.

Numerous other insects which aid in causing the death and decay of spruce might be mentioned (Pls. VIII, XI, and XII), but the two just referred to are by far the most important. There may, however, be an exception in the defoliating insects (Pl. XIII), which, it is believed, may contribute greatly to produce favorable conditions for the attack of the spruce-destroying beetle.

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[1] For a more detailed account of this beetle see Bulletin 56, W. Va. Agricultural Experiment Station, "Report on Investigations to Determine the Cause of Unhealthy Conditions of the Spruce and Pine, from 1880 to 1893," pp. 246–251.

[2] Ibid., pp. 239–242, 259, 438.

HISTORICAL REFERENCES.

In the following paragraphs attention is called to a number of early references to the death of spruce in the forests from New York to New Brunswick, probably caused by the spruce-destroying beetle:

1818.—The earliest reference to dying spruce in the Northeast is probably that contained in a letter from Hon. R. H. Gardner to Mr. A. G. Tenney, editor of the Brunswick, Me., Telegraph, and quoted by Packard.[1] Mr. Gardner stated that "he had often heard his father speak of a great destruction of timber east of the Penobscot in 1818." Dr. Packard also states[2] that he was informed by Mr. E. A. Coe, who got his information from General Smith, of Norridgewock, that "the spruce growth about that town and Waterville early in this century had been diseased and died very much as in the past few years."

1831–32.—Another early record of dying spruce is that obtained by Mr. Hough from a correspondent, Hon. Daniel W. Taylor, of Sherburne, Vt.[3]

1840.—About the year 1880 Hough[4] was informed by a correspondent in Newport, Sullivan County, N. H., "that some forty years ago the mortality of the spruce timber was very great on the hills and mountains in that part of the State * * *."

1844–1859.—When Professor Peck made his investigations of the dying spruce in the Adirondacks, in 1874,[5] he learned that the spruce had been dying for about fifteen years in Lewis County and that in Rensselaer County the same destruction had been observed about thirty years ago.

1850.—About 1850 the spruce was said to have turned red and died on about 500 acres at Irasburg, Vt., which was supposed to have been caused by worms.[6]

1871–1880—Between 1871 and 1880 great destruction occurred in the spruce from New York to New Brunswick. Hough in 1882[7] quoted information from a correspondent in Colton, St. Lawrence County, N. Y., who says of a journey made in August, 1880:

> After getting about 40 miles up the river we began to come into a region where a large part of the spruce was dead and at least half of it had lost its value. From such inquiries as could be made we learned that large portions of this timber were destroyed, including the best qualities and trees of the largest size. These injuries had been going on about ten years and were still in progress. The yield of these timber lands was about 6,000 standard of 19-inch logs to the square mile.

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[1] Fifth Report U. S. Ent. Com., p. 817.

[2] Ibid., p. 820.

[3] Report on Forestry, 1882, p. 262.

[4] Ibid., p. 262.

[5] Proc. Albany Inst., Vol. II, 1876, pp. 294–301; also Twenty-eighth Report New York State Museum, 1878, pp. 32–38.

[6] Information from J. E. Jamson, Report on Forestry, 1882, pp. 262–263.

[7] Report on Forestry, 1882, p. 263; see, also, Twenty-eighth and Thirtieth Reports New York State Museum for much additional information by Dr. Peck.

1869–1884.—In 1884 Dr. Packard was informed[1] that in the vicinity of Beed's Hotel, Keene Flats, in the Adirondacks, the spruce had been dying for the past fifteen years.

1874–1881.—In the Home and Farm, of Brunswick, Me., July 14, 1881, Mr. A. G. Tenney states, as quoted by Packard,[2] that he had been informed by an intelligent and experienced lumberman of North Somerset County, Me., that the first appearance of the insect (that killed the trees) was in 1874, and up to 1881 it was on the increase.

1876–1881.—Hough[3] states that great destruction (estimated by Mr. Robert Conners to be 1,000,000,000 feet) of spruce occurred on the Allegash and other tributaries of the St. John River in northern Maine and that these injuries extended through the spruce forests of the whole of Aroostook County and the most northern range of towns in Somerset and Piscataquis counties adjoining.

1875.—Hough[4] states that about the year 1875 the spruce timber in New Brunswick along the Mivamichi River began to die off in great abundance, the hills suffering more than the valleys, and the dense woods more than those where partial clearings had been made. The largest and best of the timber suffered most, and the young growth appeared somewhat favored, but was not wholly exempt.

1870–1873, 1880–1885.—In 1900, Mr. Cary states, in the Forester, of March, page 52, that—

> Old lumbermen tell of a great loss of spruce timber in northern Vermont and New Hampshire, extending into neighboring lands in Canada, which occurred some thirty years ago. The drives of the Connecticut River are said to have been made up for some years thereafter largely of dead timber. The same region suffered again between ten and fifteen years ago.
>
> In Maine, beginning about fifteen years ago, a township on the Androscoggin, which at the time was called the best spruce land on the river, had a large part of its value destroyed in the course of three or four years. On the Allegash River, in northern Maine, there are several adjoining townships which, about 1882, were greatly damaged. In some places 90 per cent of the spruce is said to have been killed; in fact, all of the grown timber.

1897.—In August, 1897, Fisk[5] found the spruce dying and infested with the beetles in northern New Hampshire.

Different authors and their correspondents estimate that 10, 50, and as much 90 per cent of the matured timber had died over large areas.

Different authors and correspondents have estimated that the timber was of little value after the second year, and many claim that it is worthless after the second or third year. Mr. Cary thought[6] that there was a lessening of something like 50 per cent in available timber within two years.

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[1] Fifth Report of U. S. Ent. Com., p. 818.

[2] Ibid., p. 813.

[3] Report on Forestry, 1882, p. 259.

[4] Ibid., p. 259.

[5] Bulletin 17, new series, Division of Ent., U. S. Dept. of Agr., pp. 67–69.

[6] The Forester, March, 1900, p. 53.

Probably the first mention of an attempt to utilize the dying and dead timber was by Professor Peck,[1] which is as follows:

A lumber firm found that their spruce timber was rapidly dying about 1840–1845, and to make their losses as light as possible they made haste to open roads in the forest, that they might draw out and work up as many dead spruce as practicable before decay should render them entirely worthless; but with all of their promptness they suffered no inconsiderable loss, for these dead trees soon became too much decayed to make marketable lumber.

The next mention of attempts to save the dead timber was by Hough,[2] who referred to a statement in the National Economist of Ottawa, Canada, that "one operator in New Brunswick will cut 50,000,000 feet of spruce (in 1881) because of the damage done by insects, and to save it from total loss."

Packard[3] was informed by a lumberman that the owners of the dying spruce on the St. Croix were advised in about 1875 to fell and utilize it.

REMEDIES AND METHODS OF PREVENTION.

REVIEW OF PROPOSED METHODS.

In addition to the published references to remedies and methods of preventing loss already quoted, the following should be mentioned in this connection, in order to call attention to the practical and impractical features of some of them:

Professor Peck[4] suggests the protection of woodpeckers, which, as subsequent observations by Hough, Cary, and the writer show, is a recommendation of considerable importance.

STRIPPING OFF AND BURNING THE BARK.

Peck,[5] Hough,[6] and Packard[7] all recommend cutting the dead trees and stripping off the bark and burning it to destroy the insect; but Peck and Hough expressed some doubt as to its practicability in this country. This old remedy against insect enemies of forest and other trees has been so often recommended in this and other countries that it is becoming stereotyped, but unless it is positively known whether or not the conditions are favorable, necessary, or even possible for its practical application, it should not be recommended or attempted.

As applied to the spruce-destroying beetle, this remedy would seem to be impracticable in the extreme. Indeed it would be in our American forests unsafe under ordinary conditions to attempt to burn the bark in summer on account of the danger of starting forest fires. If, on the other hand, as is the case in the Maine woods, the peeling of the logs is adopted as a business policy in the regular logging opera-

[1] Proc. Alb. Inst., 1876, Vol. III, p. 295, and Twenty-eighth Rep., pp. 32–33.
[2] Report on Forestry, 1882, p. 259.
[3] Fifth Report, U. S. Ent. Com., p. 819.
[4] Proc. Alb. Inst., Vol. III, p. 299; also 38th Report, p. 36.
[5] 28th Report, pp. 36, 37.
[6] Report of 1877.
[7] 5th Report, U. S. Ent. Com., p. 822.

tions, then the removal of the bark from infested trees in and accessible to the regular summer cuttings at a time when it is filled with the young stages of the insect is practicable, and may alone, with little additional expense, contribute greatly to the reduction of the pest. In no case, however, would it be necessary to burn the bark, either in summer or winter. The greater number, if not all, of the insects would perish from the drying of the bark in the summer, freezing in winter, and from the attack of birds and other enemies. It is true that some of the adults may escape in the summer to attack other trees, but it is believed that little trouble would result from this source.

DESTRUCTION OF DEAD TREES.

This is another method which is often recommended for the prevention of depredation by insect enemies of forests, meaning in many cases trees which have been dead a long time, as well as stumps and logs in which it is supposed destructive insects breed. As applied to insect enemies of living trees, or those which make the primary attack in living bark, the destruction of old dead trees, stumps, and logs would be worse than useless, since all of the really dangerous enemies emerge from the trees either before they are entirely dead or within one year after they die. The only apparent advantage to be gained as applied to the spruce would be the destruction of a few of the insect depredators on the wood of dead trees, and in this it would be the most exceptional cases where there would be any appreciable benefit.

GIRDLING TREES.

This is an old method practiced in Europe and quite extensively recommended, but, like most other methods, it is only applicable to certain kinds of insects and depends on specially favorable conditions for its desired effect.

INVESTIGATION OF THE GIRDLED-TREE METHOD.

Some evidence found in the felled and diseased standing trees on the first and second days of the investigation, in the vicinity of Wight's camps, suggested to the writer the importance of experiments to determine the relation of girdled trees to the attraction of the insects away from the living; therefore, the girdling of large spruce at different dates during the summer was recommended to Mr. Cary as an important line of work for him to undertake.

HACK-GIRDLED AND PEELED SPRUCE.

This subject was kept in mind throughout the investigation, and some good opportunities were had at different places to study the influence of the common practice of sportsmen, loggers, and surveyors—hack-girdling and peeling spruce to obtain the bark for camp covering.

In the vicinity of Lincoln Pond large numbers of peeled spruce were examined on May 30. The larger number of these had been peeled, as we were informed by the loggers, in July, 1898, and had

evidently died in the summer of 1899. At the time of our examination the bark was found to be infested with great numbers of Polygraphus, principally adults, also by round-headed and flat-headed bark and wood-boring larvæ, but no examples of the spruce-destroying Dendroctonus were found.

The other trees peeled in June or July, 1899, were, at the time of our examination, living, the leaves green, and the bark above the peeled portion was filled with sap. The bark of these trees was not infested by insects of any kind, so far as we could observe. The peeled trees in both lots ranged from 8 or 9 inches to possibly 18 inches in diameter, but not many of them were over 12 inches.

On June 7 some large spruce were examined near the inlet to Parmecheenee Lake which had been girdled and peeled in about 1895. One that had been hack-girdled near the base and again about 6 feet above had been infested with Dendroctonus, and the broods had

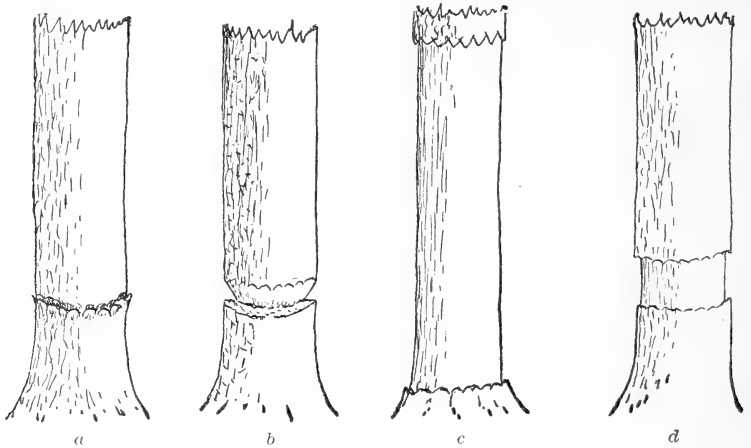

FIG. 2.—Trees girdled by different methods: *a*, Hack-girdled; *b*, girdled to heartwood; *c*, hack-girdled and peeled; *d*, hack and belt-girdled.

developed and emerged. The trees that were peeled, however, were not attacked by Dendroctonus, but had been infested by great numbers of round-headed bark and wood borers of the genus Tetropium.

On June 8 more hack-girdled and peeled spruce were examined near Rump Pond Camp, which had been infested with Polygraphus and other insects, but not with Dendroctonus.

REPORT ON GIRDLING EXPERIMENTS BY MR. AUSTIN CARY.

A number of spruce trees were girdled on May 29 and June 13 in the vicinity of Wight's cuttings on Twin Brook; on June 6 near Hamel's Camp, on the Little Magalloway; and on June 16 near Big Island Pond, at the source of the Kennebago River. Upon the writer's return home, written instructions were sent to Mr. Cary regarding the girdling experiments and observations desirable for him to make on the habits and life history of the beetle. The different methods of girdling recommended are indicated in fig. 2. The satisfactory

manner in which these instructions were carried out, the time and labor involved in the work, and the value of Mr. Cary's observations will be indicated by his report.

Mr. Cary commenced these experiments May 29; his report was submitted October 6 and 10, 1900. It is as follows:

CAMP IN THE MEADOWS, MAINE,
October 6, 1900.

DEAR PROFESSOR HOPKINS: I send you herewith report of my observations this season. They do not go very far toward solving the problems suggested, but as to Dendroctonus it seems to me they do teach considerable.

Sincerely, yours, AUSTIN CARY.

All of the trees girdled are of Red Spruce, and unless otherwise mentioned were to all appearances healthy.

The inferences to be drawn from the results depend considerably on surroundings, the lay of the land, and the relation of the girdled trees to infested and healthy ones. I will therefore group my notes according to localities.

GROUP I.

Group I is at edge of Wight's cutting of winter of 1899–1900 and near the clump of infested trees examined on May 28 by yourself and the writer. Unless otherwise stated, the trees were hack-girdled by striking an ax through the bark and into the sapwood around the trunk 3 to 5 feet above the base.

Trees girdled on May 29.

Tree No. 2: Diameter 28 inches: examined June 19, July 9, September 1, and October 4; not attacked by Dendroctonus.[1] A few Xyloterus[2] entered the wood in the girdle.

Tree No. 3: Diameter 12 inches; girdled by A. D. H.; examined on June 19, July 9, and September 1; not attacked by Dendroctonus. October 4, seemed to be losing leaves; sapwood at girdle and for a foot above stained bluish one-half inch deep.

Trees girdled June 19.

Tree No. 24: Diameter 13 inches. July 10, attacked by a few Xyloterus. October 4, no change.

Tree No. 25: Diameter 18 inches. July 10, numerous Xyloterus entering at and near girdle. October 4, no change.

These four trees are about 30 yards from infested trees and about 75 yards from the clump of trees first examined on May 28.

Tree No. 26: Diameter 20 inches; 30 yards from clump of infested trees. July 9, a few Xyloterus entering wood at girdle; bark infested with Dendroctonus, Polygraphus[3] especially abundant below the girdle; a few *Sierus annectens* found below girdle. September 1, Dendroctonus larvæ were observed. October 4, recently developed beetles and a few Tetropium larvæ occurred in the bark, with numerous Xyloterus in the wood; the bark was then loose, the leaves down, and the wood turning brown.

Tree No. 27: Diameter, 15 inches; 40 feet from infested trees. July 9, infested by Dendroctonus and Xyloterus in girdle; Dendroctonus galleries up to 3 inches long, with numerous eggs. September 1, numerous larvæ and pupæ of Dendroc-

[1] *Dendroctonus piceaperda* Hopk.
[2] *Xyloterus bivittatus* Kirby.
[3] *Polygraphus rufipennis*, Kirby-Hopkins.

tonus, also numerous Polygraphus in bark, the sapwood being stained one-half inch deep. On October 4 the bark was dry all around and the leaves falling. Dendroctonus larvæ, pupæ, and recently developed beetles being common above girdle and Polygraphus more numerous below.

Tree No. 28: Diameter, 16 inches: hollow at base and with thin crown; close to infested trees. July 9, not attacked. October 4, two Dendroctonus galleries close to girdle, but no eggs or larvæ; not attacked by Xyloterus even at girdle.

On July 9 a large tree standing by No. 27 was found to be attacked by large numbers of Dendroctonus, and by October 4 was dead and the leaves fallen. Another tree 18 inches in diameter near No. 28 was lightly attacked by Dendroctonus, and by October 4 showed numerous short galleries, but no eggs or larvæ. On October 4 it was noted that a 13-inch spruce, standing between two large infested trees 10 feet apart, had been attacked in 1899, but recovered, and was not again attacked this season. On July 9 numerous trees halfway between No. 26 and the infested trees, as well as one large tree near them, were not attacked. On June 19 I saw no signs of the beetles emerging from the infested trees, and no trees near by were being attacked. I found, however, not far away, in a stump of a tree cut last winter, four Dendroctonus galleries, and more on July 9, with many Xyloterus entering the wood, but could find no other stumps or tops of felled trees which were infested with the Dendroctonus.

GROUP II.

This group is on Wight's "tote" road, higher up the mountain, halfway to Cupsuptic divide, and in the vicinity of numerous infested trees attacked the summer of 1899.

Trees girdled May 29.

Tree No. 4: Diameter, 20 inches; close to infested tree. June 19, infested by Dendroctonus. July 11, abundantly infested, the galleries being as much as 3 inches long and containing eggs; Xyloterus common, entering wood at girdle and elsewhere. September 1, many of the leaves had fallen, and recently developed beetles, pupæ, and large larvæ were found in the bark, with no trace of parasites. October 4, all the leaves fallen; numerous nearly matured adults of Dendroctonus, with few larvæ and pupæ.

Tree No. 5: Diameter, 16 inches; 40 feet to nearest infested tree. June 19, infested by Dendroctonus. July 11, Xyloterus in the wood and Dendroctonus in the bark, but apparently not in great numbers. September 1, Dendroctonus abundant, with pupæ and large larvæ; majority of the leaves fallen. October 4, leaves nearly all down; recently developed beetles, some fully matured; also large larvæ and pupæ, with some parasites and one Tetropium larva.

Tree No. 6: Diameter, 15 inches; belt girdled by removing a belt of bark 8 inches wide; located 50 feet away from nearest infested tree. June 19, infested by Dendroctonus. July 11, galleries 3 inches long, with eggs. September 1, majority of leaves fallen; Dendroctonus abundant in bark. October 4, leaves nearly all down; pupæ, matured larvæ, and recently developed beetles of Dendroctonus, with a few parasites; also a smaller bark beetle than Dendroctonus.

Tree No. 7: Diameter, 22 inches; girdled by cutting through the sapwood. June 19 and July 11, not infested. September 1, most of the leaves fallen and the wood is drying without staining; a few, possibly eight, Dendroctonus galleries observed, but very short and without eggs or larvæ; also some Polygraphus and several Tetropium larvæ in bark. October 4, same condition; wood not stained.

Trees girdled September 1.

Tree No. 43: Diameter, 13 inches; a few rods from infested trees. October 4, not infested and in normal condition.

Tree No. 44: Diameter, 13 inches. October 4, in normal condition.

Tree No. 45: Diameter, 13 inches; near infested trees. October 4, in normal condition.

Of the four trees girdled here May 29, three were infested by Dendroctonus June 19, this being the first new work of the season observed. Some of the galleries were then 2 inches long. They had numerous eggs, and one ventilation hole was observed started, but not through. The beetles in the galleries in some cases were both black, and in others both bronze, or one bronze and one black.

In order to get further information in this locality, a half acre was laid out by guess, which included all the girdled trees as well as the dead ones and those infested last year. All of the trees were examined and their local relations to the probable source of infestation noted on June 19. The conditions were again studied on October 4, and the results are given below. All trees 10 inches or less in diameter standing on the half acre are omitted.

Condition of trees, over 10 inches in diameter, on one-half acre of land.

Diameter.	Condition June 19.	Condition October 4.
In.		
20	Killed in 1898 or 1899	
18	Killed in 1899; infested with Dendroctonus pupæ, etc.	Sapwood brown and soft; Polyporus fungus on bark.
22	Killed probably in 1898	
25	Killed in 1899, infested with Dendroctonus pupæ, etc.	Sapwood brown and soft.
22	Killed in 1899; infested with pupæ and beetles.	Sapwood brown, streaked and softening. A few Polyporus on bark.
17	Killed probably in 1898	Sapwood on one side rotten; remainder brown and softening; Polyporus on bark.
18	Killed two or three years ago	
16	Attacked last year, but not this; leaves green, but wood and bark drying.	Leaves fallen; wood and bark dry.
20	Hack-girdled; attacked by Dendroctonus. (Tree No. 4, Group II.)	Leaves all fallen; wood and bark drying.
13	Two roots extending into road damaged; attacked by Dendroctonus.	Wood dry; leaves falling.
18	Attacked by Dendroctonus	Majority of leaves fallen; wood dry and browning.
20	Probably infested last year and again this; bark dead on one side.	All dead; leaves fallen; sapwood browning.
22	Girdled through sapwood; not attacked. (Tree No. 7, Group II.)	Wood drying without stain; 8 Dendroctonus galleries without progeny.
14	Attacked by Dendroctonus last year; not again this; strip of bark and wood on one side dry; top green.	Not attacked; living bark covering scars; leaves still green.
13	Attacked last year; infested with beetles and pupæ; no fresh infestation; part of wood dry; top green; Xyloterus in roots.	Previously dead wood decaying; leaves yellow and majority fallen.
15	Attacked last year, but no work of larvæ; not attacked this year.	Not attacked; old scars healing.
15	Belt-girdled; attacked. (Tree No. 6, Group II.)	Dead; leaves nearly all fallen.
16	Hack-girdled; attacked. (Tree No. 5, Group II.)	Majority of leaves down.
12	Hollow at base; small crown; lightly attacked.	Larvæ and pupæ of Dendroctonus abundant.
18	Attacked this year	Dying all around; leaves nearly all fallen; infested by Dendroctonus and Tetropium.
15	Not infested	Not infested.
14	....do	Do.
11	....do	Do.
12	....do	Do.
13	....do	Do.
14	....do	Do.
15	....do	Do.
16	....do	Do.
11	....do	Do.
18	....do	Attacked and killed; leaves fallen; strips of wood browning.
12	Fine thrifty tree	Infested; many Dendroctonus galleries, but no eggs nor larvæ; leaves not fallen.
20	A heavy-crowned tree	Abundantly infested by Dendroctonus, mainly in pupa stage; leaves not fallen.
15	Living	Abundantly infested; bark dry all around; leaves not fallen.
12	Not attacked	Not attacked.

Three of the four trees girdled on May 29 were infested by large numbers of Dendroctonus on June 19, but there were many other apparently healthy trees which were also attacked. At this date no newly infested trees were noticed that were more than 50 feet away from the source of infection. Later the infestation extended farther, but still it appeared that the trouble spread but slightly beyond the limits of the half acre. Among the trees lightly attacked in 1899 only 1 was reattacked and killed this year. Indeed, it seems that if a tree recovers from the first attack it usually escapes the next year. Numerous examples of this have been observed.

Of the 34 trees noted on the one-half acre, 7 had been dead from one to three years; 4 ungirdled living trees were attacked in June of this year; 4 were not attacked in June, but were infested in October. Of the 4 girdled trees the 2 that were hack-girdled and the 1 that was belt-girdled were infested and died, while the 1 that was girdled to the heartwood died without the aid of Dendroctonus. Two trees attacked last year recovered and were not attacked this. Two attacked last year died this. Eleven trees were not attacked.

The 9 trees that were dead on June 19 averaged 19.3 inches in diameter. The 8 ungirdled trees that were attacked this year averaged 15.7 inches in diameter. The 3 girdled trees that died averaged 16.7 inches in diameter. The 13 trees that were not attacked averaged 14.2 inches in diameter.

Group III.

This group is situated on the "tote" road, near the brook crossing near Wight's Camp.

Trees girdled June 13.

Tree No. 16: Diameter, 17 inches; sound roots, and healthy crown. June 19, two Dendroctonus galleries, one at girdle, the other 1½ inches long. July 11, about a dozen Dendroctonus galleries, the longest ones 2 inches; without eggs or larvæ; several single beetles dead in short galleries and embedded in the pitch. September 1, six or eight new galleries, without eggs or larvæ.

Tree No. 17: Diameter, 15 inches; hack-girdled at base of roots. June 19, not attacked. July 11, one Dendroctonus gallery with eggs. September 1, one gallery without larvæ. October 4, no additional attack; tree still living.

Tree No. 18: Diameter, 17 inches; sound roots, and large crown; an infested tree 20 feet away. June 19, lightly infested by Dendroctonus; galleries about 1 inch long; had entered at girdle and elsewhere; also some Xyloterus in girdle and elsewhere. July 11, thoroughly infested by Dendroctonus; galleries 3 inches long; Polygraphus (?) also in bark. September 1, thickly infested with Dendroctonus, mainly in the pupa stage; Xyloterus in wood; sapwood brown and blue; leaves falling. October 4, recently developed adults and numerous Xyloterus; leaves half fallen.

A 19-inch tree, the same distance from the infested trees, as well as others 40 feet away, were not attacked.

Tree No. 19: Diameter, 17 inches; sound roots and full top. June 19, not attacked. July 11, abundantly infested by Dendroctonus; Xyloterus in girdle. October 4, large larvæ, pupæ, and partly and fully developed adults of Dendroctonus.

The above trees were all at the time of girdling within a few rods of infested trees.

Tree No. 20: Diameter, 15 inches; standing in group of trees killed last summer; roots sound. July 11, infested with Dendroctonus; some galleries 4½ inches long, containing eggs, but none hatched. September 1, abundantly infested with Dendroctonus, pupæ, and large larvæ. October 4, large larvæ to light-colored beetles.

July 11, two other trees in same bunch, not girdled, were found to be attacked. I am not certain that they were killed, but think that they were not.

Trees girdled July 11.

Tree No. 35: Diameter, 15 inches; 50 feet from infested trees. September 1, two Dendroctonus galleries, but without larvæ; no Xyloterus. October 4, same condition.

Tree No. 36: Diameter, 15 inches. September 1, lightly infested by Dendroctonus, with small larvæ. October 4, thickly infested; bark drying all around; larvæ half grown.

Tree No. 37: Diameter, 18 inches; 30 yards from infested tree. September 1, thoroughly infested by Dendroctonus; half-grown larvæ; leaves beginning to fall. October 4, medium and large larvæ abundant; bark dying; leaves partly fallen.

Tree girdled September 1.

Tree No. 40: Near No. 37. October 4, not attacked.

Aside from the trees mentioned above, girdled and ungirdled, no other trees were attacked in the immediate vicinity of this group; therefore, it would appear that the girdled trees had exerted considerable influence in attracting the beetles.

GROUP IV.

This group of trees is situated on the trail north of Wight's Camp.

Trees girdled July 11.

Tree No. 31: Diameter, 18 inches; away from infested trees. October 4, not attacked by any insect.

Tree No. 32: Diameter, 17 inches; near No. 31. October 4, three Dendroctonus galleries about 3 inches long; one at the girdle.

Tree No. 33: Diameter, 20 inches; standing with trees girdled last year; no living beetles found in the bark. September 1 and October 4, not attacked even by Xyloterus.

Tree No. 34: Diameter, 17 inches; away from infested trees. September 1 and October 4, not attacked.

Trees girdled September 1.

Tree No. 41: Diameter, 13 inches; standing among dead and infested trees October 4, no evidence of attack; mold in the girdle.

Tree No. 42: Diameter, 14 inches. October 4, not attacked.

GROUP V.

This group stands near the outlet of Big Island Pond at the head of Kennebago River, where much infested timber was observed on date of girdling.

Trees girdled June 16.

Tree No. 21: Diameter, 16 inches; standing among infested trees. July 28, a few Xyloterus entering at girdle, but no Dendroctonus. August 11, same condition.

Tree No. 22: Diameter, 16 inches; near infested trees. July 26, one Dendroctonus and a smaller species at girdle. August 11, two Dendroctonus, with larvæ in bark below girdle.

Tree No. 23: Diameter, 17 inches; with hollow base but externally sound roots; close to infested trees. July 26 and August 11, not attacked.

On July 26 no recent infestations were observed in this locality, although many badly-infested trees were observed here on June 16, in which Professor Hopkins found a far greater number of parasites and predaceous beetles than had been found in any other locality. On August 11 a group of three infested trees was found, which was probably overlooked in July. One of them was infested by

Dendroctonus, Polygraphus, and Xyloterus; another showed numerous Dendroctonus galleries, and the third, a 12-inch tree with decayed roots, had numerous Dendroctonus burrows reaching to the wood, but not completed. Near these trees two others were observed that had each a decayed root, but were not attacked; another 14-inch tree, attacked in 1899, had recovered and was not attacked this year; another one, 20 inches in diameter, with the bark dead on one side half around the trunk, was not attacked. Still another tree, with a long split or fissure in one side, had been attacked last year and died on one side, but the other side was not attacked this year. One of two large living trees standing by the side of one that died last year had two full-length Dendroctonus galleries in the bark, but no larvæ. One Tetropium pupa case was observed in the sapwood.

Stumps of trees cut last year within 10 rods showed no evidence of attack by Dendroctonus, although Xyloterus (pupæ and immature adults) and small bark beetles were common.

GROUP VI.

This group is at Hamel's Camp, on the line of 5 R. 5 and 5 R. 4, within a mile of the New Hampshire line.

Trees girdled June 6.

Tree No. 8: Diameter, 18 inches; heartwood decaying; external wound; one root decayed; 100 yards from infested tree. October 9, tree broken off; bark dry; leaves all fallen; Polygraphus abundant in bark, but no Dendroctonus.

Tree No. 9: Diameter, 17 inches; thrifty, with sound roots; 50 yards from infested trees. October 9, infested with Dendroctonus, pupæ and adults, also Polygraphus and Xyloterus; leaves fallen; wood drying and staining.

Tree No. 10: Diameter, 14 inches; full crown and thrifty; 50 yards from infested trees. October 9, infested with some Dendroctonus; more Polygraphus; also Xyloterus and a few Tetropium; leaves fallen and wood dying.

Tree No. 11: Diameter, 18 inches; close to infested tree; full crown; unsound roots; probably the lower portion of the trunk hollow. October 9, fallen; probably blown over about September 1; not attacked by insects.

Tree No. 12: Diameter, 17 inches; sound roots and full crown; dead and infested trees near by. October 9, infested with Dendroctonus; galleries abundant; adults occur in small numbers; wood attacked by Xyloterus; bark dry and leaves fallen.

Tree No. 13: Diameter, 19 inches; heavy crown and sound roots; 2 rods from infested tree. October 9, infested with numerous Dendroctonus; broods developed to adults; Polygraphus and Tetropium in bark, and Xyloterus in wood.

Tree No. 14: Diameter, 13 inches; standing among others of the same size and larger; all thrifty; 3 rods to infested trees. October 9, infested with Dendroctonus; fully developed broods; also infested with Polygraphus and Xyloterus; leaves fallen; wood dry.

Tree No. 15: Diameter, 16 inches; full crown and sound roots; standing close to infested trees. October 9, infested by fully developed broods of Dendroctonus; wood drying, but the majority of the leaves holding on.

Peeled trees.

About June 20 a considerable number of trees were peeled 5 feet up from base by the loggers here. One was hack-girdled for peeling, but was not peeled. This tree was attacked by Dendroctonus, and at this date, October 9, the bark is full of half-grown larvæ, but the leaves are green. Among a number of peeled trees standing near girdled trees Nos. 9 and 10 one has a few Dendroctonus at the base; another is infested with Polygraphus in large numbers and the leaves are falling; another one is losing its leaves, but apparently not infested; still others are yet living, but about half of them have a number of Dendroctonus galleries.

A living wind-felled tree here was not attacked. Near No. 11 there are a number of peeled trees, two of which have a few Dendroctonus galleries at the base. Several have Xyloterus and Tetropium, but no evidence of attack has been noticed above the peeled portion. The leaves on all of them are green, but some are beginning to fade. A small log cut near by and left is full of Polygraphus, but contains no Dendroctonus. No Dendroctonus were found here in stumps of last winter's cutting.

Notes accompanying the report.

The first activity of Dendroctonus was noted near Wight's on June 19, where a tree girdled on June 13 had galleries in the bark as much as 1½ inches long, with eggs. Trees girdled on May 29 and others had galleries 2 inches long. At other places I failed to note activity of the insects on this date, except four or five burrows in a stump, although I looked for it carefully in infested clumps of trees.

The first larvæ were noticed between July 28 and 31 at Big Island Pond. They had then worked about an inch laterally from the parent galleries.

On July 11 the trees at Wight's which were first infested had galleries as much as 3 inches long, with eggs, but no larvæ. On September 1 the same trees showed the insect mainly in the pupa form; also some large larvæ and recently developed beetles. On October 4 the broods were largely in the full-colored or matured adult form, though some lagged behind, even remaining in the larval form. At this date I could see no signs of any of the beetles emerging, although I looked carefully.

The trees girdled in June and July indicate the time required for the development of the insect. The trees girdled on September 1, I believe, were in no case attacked by insects.

We had a very wet June, and early July was also wet, but the weather was dry in late summer. On September 1 the leaves had not commenced to turn, but by October 1 about half of the leaves of the maples had fallen.

In my identification of the insects I was not always certain about Tetropium and Polygraphus.

The woodpeckers that work on infested trees are probably American and Arctic three-toed woodpeckers. There may be others. They do little work in the summer.

It seems that any exposure of the wood—as in girdling—attracts Xyloterus and possibly Dendroctonus.

Trees are frequently met with which are attacked quite abundantly by Dendroctonus, which excavate galleries, but no broods develop. Such trees frequently at least—I think generally—escape attack the next year.

My inference as to the attraction exerted by girdled trees is that while many beetles are attracted to them, yet the attraction is not great or from a long distance. The evidence furnished by Group III is affirmative on this point. The results with Group II are inconclusive, mainly from the abundance of the beetles here, but also from exemption of tree No. 7. The results in the case of Group I seem to show that distance is a bar, while those with Group II further indicate that the broods migrate only a short distance. The evidence furnished by trees Nos. 26, 27, and 28 in Group I is affirmative, but the surroundings are such that the test is inconclusive. From Groups IV and V, I can draw no striking or certain conclusions, while Group VI is the most affirmative of all.

As to windfalls, I can only state from general impression that in my opinion they are not specially liable to attack by Dendroctonus, and that the same is the case with logs left in yards, tops left in woods, etc.

The fact that 6 of the 9 trees girdled on June 6 were infested and killed, while no others near by were attacked, is strong evidence that the girdled trees attracted the insects.

COMMENTS ON MR. CARY'S WORK.

The experimental work of Mr. Cary and its results are summarized in the following table. The data are arranged in the numerical order of the trees experimented with.

Summary view of Mr. Cary's work.

Number of tree.	In what group.	Diameter of tree.	Date of girdling.	Results to October 4 to 9.
		Inches.		
2	I	28	May 29	Not attacked; living.
3	I	12	do	Not attacked; dying.
*4	II	20	do	Attacked; dead; leaves fallen.
*5	II	16	do	Do.
*6	II	15	do	Do.
†7	II	22	do	Not attacked; dead; leaves fallen.
8	VI	18	June 6	Not attacked; tree blown down.
*9	VI	17	do	Attacked; dead; leaves fallen.
*10	VI	14	do	Do.
11	VI	18	do	Not attacked; blown down.
*12	VI	17	do	Attacked; dead; leaves fallen.
*13	VI	19	do	Do.
*14	VI	13	do	Do.
*15	VI	16	do	Attacked; dying; leaves not all fallen.
†16	III	17	June 13	Attacked; living.
†17	III	15	do	Do.
*18	III	17	do	Attacked; dead; leaves fallen.
*19	III	17	do	Attacked.
*20	III	15	do	Do.
21	V	16	June 16	Not attacked; living.
†22	V	16	do	Lightly attacked; living.
23	V	17	do	Not attacked; living.
24	I	13	June 19	Do.
25	I	18	do	Do.
*26	I	20	do	Attacked; dead.
*27	I	15	do	Do.
28	I	16	do	Not attacked; living.
31	IV	18	July 11	Do.
†32	IV	17	do	Lightly attacked; living.
33	IV	20	do	Not attacked; living.
34	IV	17	do	Do.
†35	III	15	do	Lightly attacked; living.
†36	III	15	do	Attacked; dying.
*37	III	18	do	Attacked; dying; leaves partly fallen.
40	III	----------	Sept. 1	Not attacked; living.
41	IV	13	do	Do.
42	IV	14	do	Do.
43	II	13	do	Do.
44	II	13	do	Do.
45	II	13	do	Do.

* Trees exerting decided attraction. † Trees lightly attacked.

Of the four trees hack-girdled and one tree belt-girdled on May 29, two hack-girdled and the one belt-girdled were attacked. One tree girdled to heartwood was not attacked.

Of the eight trees hack-girdled on June 6, six were attacked and two, having diseased wood and roots, fell without being attacked.

Of the five trees girdled on June 13, all were attacked.

Of the three trees girdled on June 16, two were not attacked and one but lightly.

Of the five trees girdled on June 19, two were attacked and three were not.

Of the seven trees girdled on July 11, two were attacked seriously, two lightly, and three not at all.

Of the six trees girdled on September 1, none were attacked.

Of the fourteen trees girdled on June 6 and 13, all but the two that

fell were attacked by large numbers of Dendroctonus, thereby furnishing good evidence that between these dates was the proper period (spring of 1900) to girdle the trees to attract the insects.

Of the twenty-five trees girdled on the other dates—May 29, June 19, July 11, and September 1—only seven were attacked by sufficient numbers to kill the trees.

These results, together with observations by the author during the investigations on the dates of the appearance of the leaves and flowers on different trees, indicate that the best period to girdle spruce trees to attract the spruce-destroying beetle away from other trees may vary with the seasons, but will be about ten days, commencing when the catkins (flower stems) are falling from the birches, and continuing while the fire cherry and the hobble bush are in flower. Another good guide will be to commence when the first pupæ of the destructive beetle commence to appear in the bark and continue until the beetles commence to fly.

SUGGESTIONS AND RECOMMENDATIONS.

The prime objects of the investigation were not only to determine facts relating to the causes of the death of the spruce, but to obtain evidence on which to base suggestions and recommendations for mitigating or controlling the ravages of the spruce-destroying beetle; preventing the total loss of the vast amount of timber already killed, and for reducing or preventing the losses from its ravages in the future.

It has seemed a hopeless undertaking to determine practical methods of combating invasions of destructive insects in a vast wilderness of virgin forest, or to accomplish much toward preventing total loss of the millions of feet of timber killed or injured by them, especially in a country like ours, where improved forestry is in its infancy. But with a knowledge of the principal depredator, its habits, its life history, its enemies, and the conditions, favorable or unfavorable, for its destructive work, facts have been determined on which to base conclusions relating to simple, inexpensive, and practical methods of combating the insects and preventing a large part of the losses.

It then rests with the owner of the property to study the practical features of the problem and the facts determined by the investigator, in order that he may intelligently apply the recommendations to the varying needs and conditions as in each case seems most advisable. It should be remembered that it is the investigator's mission to determine the facts and evidences, and present them with recommendations and suggestions, while the owner of the damaged or threatened property must study and utilize or discard them, as his practical judgment and business interests may indicate is best in each particular case.

METHODS OF REDUCING THE NUMBER OF BEETLES.

The fact that a large number of beetles must attack a living, healthy tree in order to inflict injury sufficient to cause its death, and thus offer the best conditions for its future multiplication and spread, is of special importance since, if their numbers can be reduced below that necessary to kill the trees, their depredations on the living timber must end. The insect can then only survive in weakened, dying, or felled trees. It would thus remain harmless until some specially favorable condition would enable it to accumulate, or migrate from a distance, in sufficient numbers to again successfully invade the living timber.

The facts which have been determined regarding the habits and life history of the beetle suggest three methods by which their numbers can be reduced:

I. To regulate the winter logging operations so that as many of the dying and infested trees as possible can be cut and the logs therefrom placed in rivers, ponds, or lakes between October 1 and June 1.

Different stages of the Dendroctonus remain in the bark during the summer, cease active work about the middle of October, remain in the bark over winter and until about the middle of June before the adults emerge. The part of the trees that is infested is that which is utilized for logs. Therefore, if the trees are cut any time after they become thoroughly infested, and the logs are hauled to the landings in the winter, placed in the water and driven out of the woods in the spring, vast numbers of the insects will be either drowned or so far removed from the larger standing spruce that they can do no harm. There are eight months in which to do the work; so if the regular logging operations are (as suggested by Mr. Cary) turned in the direction of the worst infested areas there will be little additional expense in the practical application of this method.

II. To regulate the summer operations so that as many of the infested trees as possible can be cut while the bark will peel, by the removal of which from the logs and stumps of such trees most of the insects will be destroyed.

It is the practice in some sections to cut the spruce at a time when the bark can be readily removed, thus facilitating transportation to the mills; therefore, if the cutting can be turned in the direction of the dying and infested spruce, there will be little or no additional expense in cutting and removing the bark from such trees, and thus all of the eggs and young stages of the beetle will be effectually destroyed by the exposure and the drying of the bark. Another advantage of this method, it would seem, lies in the fact that trees peeled either in the winter or summer can, if necessary, be left in the woods for several years, probably without serious detriment. The preservation of such peeled logs could be facilitated by placing some of the removed bark along the tops of the logs to prevent undue

checking and give some protection from the elements. Such logs could then be taken out when reached in the regular cutting and logging operations.

III. To girdle healthy trees in June to attract the beetles away from timber that it is desired to protect, the girdled trees to be cut and peeled, or placed in the water, in the ordinary practice of logging, previous to the first of the following June.

The use of girdled trap trees has the advantage of not only facilitating the destruction of the insects, but of attracting them away from the matured timber that it is desired to leave standing for future cutting. Still another advantage lies in the fact that trees may usually be selected for this purpose which in the regular logging operations could be cut and hauled to the streams within the limited time required. The beetles which are attracted to the trees in this manner may be disposed of by either of the preceding methods mentioned, so that the only additional expense over the regular logging operations would be the cost of girdling.

The infested spruce which can not be reached by the extension or adjustment of the summer and winter logging operations might be felled and the bark removed from the infested portions of the trunks any time between the first of August and the first of the following June. The young stages of the insects and most of the adults would thus be destroyed by the drying of the bark in summer, or by freezing if removed in the winter.

Another method would be to fell and "score" (by cutting through the bark) the top of the infested portion of the felled trunks or logs to let in the water, which, it is believed, would thus produce an unnatural condition which would kill most of the insects. Experiments are suggested to test the effects of water absorbed by the unpeeled logs whether left in the woods or placed in the water. The adoption of this method is not recommended, however, until experiments prove its value and the conditions are found to be favorable for its practical application.

When the timber is dying rapidly in a given area of greater or less extent, and the trouble is perceptibly spreading, and upon examination it is found that there are comparatively few insect enemies of the beetle, either or all of the three methods should, under favorable conditions for their practical adoption, prove of great service in preventing the undue multiplication of the pest and protecting the living timber from attack.

If the trouble seems to be on the decrease, and upon examination it is found that a large number of natural enemies are operating on different stages of the spruce beetle, it may not be necessary to take active measures for reducing their numbers. Indeed, under specially favorable conditions for the enemies to operate, it may be best to do nothing, for under such conditions an attempt to destroy the enemy

of the spruce would result in destroying the natural enemies of the spruce beetle also.

This is, however, a problem requiring considerable knowledge of the subject. Indeed, it is difficult even for one having such knowledge to determine whether or not it is best to leave the matter to be taken care of by friendly insects and conditions. Under ordinary conditions it will probably be as well to adopt by way of precaution one or more of the simple methods suggested.

While it may not be best in some cases to cut and remove the infested trees when beneficial insects abound, the reverse is the case when applied to the beneficial woodpeckers.

If, as has been made clear by the abundant evidence found, the birds destroy a large percentage of the spruce-destroying beetles in thousands of infested trees during a single winter, it is plain that if these birds had to confine their work to a half or a quarter as many trees, very few of the insects would escape. For every infested tree taken out of the woods through the adoption of either of the three methods suggested, that many less will remain for the birds to work on and consequently fewer beetles would escape to invade the living trees.

Previous observations by the writer, and a study of the problem of the relation of birds to injurious and beneficial insects, led him to believe that in the end far less service was rendered by the birds than was generally credited to them. This was believed to be the case mainly on account of the failure of the bird to show any decided preference for the injurious over the beneficial insects. In the case of the woodpeckers of the Maine woods, which feed on the spruce-destroying beetle, however, the writer is convinced that, while the birds may, and doubtless do, destroy many insect enemies of the Dendroctonus, they do far greater good than harm. It would seem, however, that the relation of the birds to the beneficial insects of the northern spruce forests presents some novel features which either do not exist or have not been noted in other sections of the country.

The adults and larvæ of the common Clerid beetles are among the most efficient insect destroyers of bark beetles. In other sections the larvæ of these friendly insects, as a rule, after they have attained their full growth, go into the outer bark to undergo their transformations and to pass the winter. Here they are in especial danger of destruction by the woodpeckers. It appears, however, that in the northern spruce woods they have learned, possibly through the survival of the fittest, or the perpetuation of an acquired habit, to escape the birds by going into the central tubes or tunnels in the main galleries made by the spruce beetles to construct their pupa cases and undergo their transformations.

It is also probable that the habit of the principal parasite of the spruce beetle, which makes its cocoons in the inner bark, may enable it to escape the birds. The fact, also, that these parasites must have

thin bark through which to insert their ovipositors and reach the Dendroctonus larvæ when depositing eggs suggests that this class of beneficial insects may be favored in their work by the removal of the outer thick bark by the bird. Thus the parasite would be able to kill many of the beetle larvæ that escape the birds.

If the spruce-destroying beetle should become rare, through the efforts of the lumbermen and the work of birds and other natural enemies, the lumbermen might repay the birds for their great services by providing food for them. This could easily be done by girdling to the heartwood numbers of spruce trees in June and leaving them stand until the following spring. These would be infested by numerous other bark beetles, like Polygraphus, which breed in the cuttings and are readily attracted to injured trees. Flat-headed and round-headed bark-mining grubs would also be attracted to and breed in such trees and would furnish food for the birds. The trees could be cut in the spring following, so that there would be no loss and possibly much gain.

The owners of the spruce of the Northeast owe a lasting debt of gratitude to these friendly birds, and should exert every possible effort to protect them and increase their numbers so that their good work may continue.

UTILIZATION OF DEAD SPRUCE.

While this is an economic problem for the consideration of the expert practical forester, it may not be out of place for the writer to contribute the results of his observations, which, if not authoritative on such a question, may at least be suggestive.

The observations of the writer led him to believe at the time the investigations were being made that a considerable quantity of the dead timber which had been dead five to fifteen years or more (Pl. XIV) had yet considerable value, especially as pulp wood. He was all the more convinced of this after a recent visit to the spruce areas in West Virginia, where it was found that just such dead standing and felled spruce as was observed in Maine was here furnishing a large amount of sound pulp wood. Upon examination of this wood in the yard and in the trees before and after they were felled it was found that some of the trees from which considerable good material was secured had been dead at least twenty years. Nearly all were known to have been dead at least seven years, and this in a section where previous investigations indicated that the wood decays more rapidly than elsewhere.

The advantages of utilizing the wood of dead timber for pulp over that for ordinary lumber is in the fact that it can be cut into short lengths, the good taken and the bad left in the woods. The profitable utilization of such material depends, of course, upon the cost of getting it out of the woods, as well as convenient and moderately cheap

transportation to the factories. In the mountains of West Virginia this problem is solved by broad and narrow gauge railroads, with branch tramroads running through the forest, the latter extending into and following up the cuttings. Therefore the cost of taking out the dead along with the living timber is a small item.

The determination of the relative value of the dead timber and its rate of deterioration under different conditions and in different localities, together with recommendations for the practical utilization of that which is worth saving, is a problem which will doubtless receive its due share of attention from Mr. Cary and other expert foresters in northwestern Maine. Mr. Cary is in an ideal position for the future investigation of such matters. The knowledge recently gained by him from being with Dr. Von Schrenk in his investigation of fungous diseases of trees, and the writer, in the investigation of the insect enemies, will probably render the results of his further investigations all the more valuable.

It is plain that, if as large a percentage of the wood of the dead trees remains sound for as long a period as our observations would indicate, the amount to be saved in its utilization at as early a date as possible would go far toward paying the expenses of extending roads for the purpose far in advance of the regular cutting.

IMPORTANCE OF HARVESTING THE MATURED CROP OF SPRUCE.

Since it has been definitely determined that the spruce-destroying beetle confines its attack to spruce trees over 10 inches in diameter, and that by far the larger percentage killed by it range from 18 to 24 inches, it seems clear that the matured or large timber should be harvested as rapidly as is consistent with good business management. This would not only save the larger living trees from attack, but would facilitate the utilization of such of the dead trees as may yet yield a quantity of merchantable material.

This is a problem, however, like the preceding, which must be considered from the standpoint of the expert forester, and, in its application, made to conserve the best interests of the timber owners. It has, therefore, been the writer's intention to do no more than to call attention to what has been learned of the relation of the spruce-destroying beetle to the virgin spruce areas and matured timber as an important factor to be considered in future management.

Mr. Cary refers to the subject of cutting the spruce in damaged and endangered localities in The Forester, March, 1900, page 54, as follows:

> There need not be, under present conditions, any comparatively great loss. Extensive lumbering is being carried on throughout the region in which the insect is known to exist. The bodies of uncut timber are nearly all accessible. Cuttings can be turned in the direction of the damaged or endangered localities, and cutting serves not merely to save the dead timber to us, but also, it would

appear, to carry away much of the source of infection. The bunchy way in which the dead timber stands is also in our favor. Evidently the normal flight of the beetle is short, for the dead trees, as a rule, stand in groups; those killed one, two, or three years ago, together with the insect colony working perhaps in green timber close beside them. This trouble, indeed, may also be regarded, in one way, as a benefit to our forests. So far as it may determine a policy of thinning rather than stripping the land, it will exert a favorable action which will never be entirely lost on the reproduction of spruce.

SUMMARY.

The results of the investigation and review of literature relating to the unhealthy condition of the spruce in the Northeast may be summarized as follows:

Extensive dying of spruce from New York to New Brunswick has occurred at various times and periods from about 1818 to 1900.

Within this period spruce to the amount of many billions of feet has died, and much of it has been a total loss.

The cause of the death of a greater part of this spruce has been the depredations of insects.

The primary depredator in the forests investigated is a bark-mining beetle, the spruce-destroying beetle, *Dendroctonus piceaperda*, n. sp.

Vigorous trees, to all appearances in perfect health, are attacked and killed by this beetle.

The largest trees and best stands of timber suffer most from its ravages.

It passes the fall, winter, and spring in all stages from young to matured larvæ, and immature to matured and old adults, in the bark of trees attacked by it in the summer.

Activity commences early in June; the beetles commence to emerge from their winter quarters about the middle of June, and continue to come out probably until about the 1st of September.

In the latitude and altitude of northwestern Maine there is but one brood of the insect each year from the first parent beetles that emerge in June, while those that emerge later in the summer do not develop broods of adults until the next summer.

The broods of the beetle do not remain in a dying or dead tree more than one year after it commences to die. The estimated number of adults which, under favorable conditions, may emerge from an average-sized tree is from five to seven thousand.

It is estimated that an average of three pairs of beetles to the square foot of bark on 10 to 15 feet of the trunk of an average-sized tree are sufficient to kill it, and that 6,000 beetles breeding in one tree may be sufficient to kill from 20 to 25 more trees.

The principal insects that aid the primary enemy in killing the trees after the first attack has been made are (1) a smaller bark beetle (*Polygraphus rufipennis*) and (2) a round-headed bark and wood miner (*Tetropium cinnamopterum*).

There are many other bark-mining beetles and bark and wood-mining grubs which may aid the primary enemy in killing the trees and in the subsequent destruction of the wood.

The principal enemy of the spruce-destroying beetle and other bark-infesting enemies of the spruce consists of the woodpeckers, which destroy, it is believed, from 50 to 75 per cent of the broods of the spruce beetle in many hundreds of trees each year.

Two other enemies of the beetle are of special service in reducing their numbers, a small wasp-like parasitic insect (*Bracon simplex*) and an ant-like predaceous beetle (*Thanasimus nubilus* Kl.?).

The principal methods recommended in this report for preventing losses from the ravages of the beetle may be briefly summarized as follows:

I. Regulating the winter cutting so as to include as many of the infested, dying, and dead trees as possible, and placing the logs from the same in the water before the 1st of June.

II. Regulating the summer cutting so that as many recently attacked trees as possible may be cut and the bark removed from their trunks and stumps.

III. Girdling, early in June, a large number of trees, where logging operations will, or can, be carried on the following summer and winter, in the vicinity of infested localities, the girdled trees to be felled and the logs containing the broods of the insect attracted to them either peeled or placed in the water before the first of the succeeding June.

The results of one season's experiment in girdling trees indicate that the best time to girdle spruce for this purpose is when the flowers (catkins) are falling from the birch, and while the fire or bird cherry and the hobble bush are in bloom. The girdled trees should be sound and healthy, and not less than 15 inches in diameter.

The best method of girdling seems to be that of hacking through the bark with an ax into the sapwood and around the trunk 2 or 3 feet above the base.

Suggestions for utilizing the dead and matured living spruce to prevent loss are as follows:

A large percentage of the dead spruce appears to remain sound and valuable for pulp wood for a longer period than has heretofore been recognized.

The matured living timber should be cut and utilized as rapidly as possible to prevent insect attack.

EXPLANATION OF PLATES.

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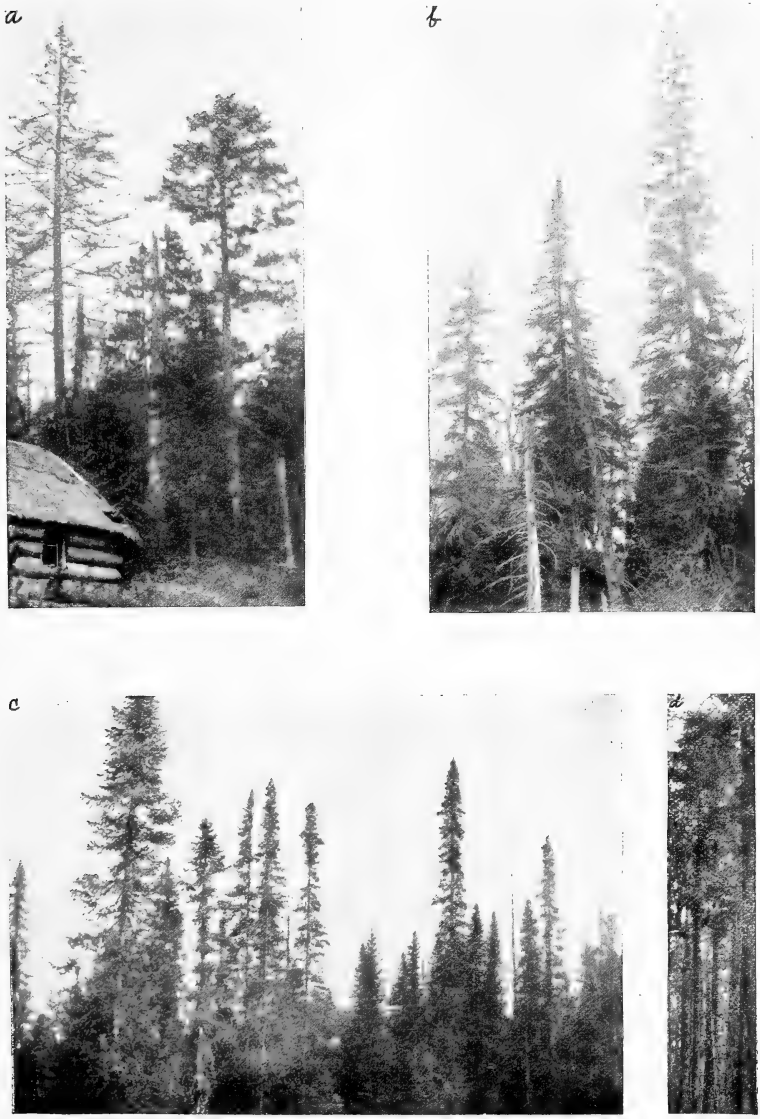
PLATE I.

The spruces of Maine.

a, Red Spruce, dead and living trees at gamekeeper's camp.
b, White Spruce, near Wight's camp.
c, Black Spruce, on trail to Lower Black Pond.
d, In dense spruce woods.



THE SPRUCES OF MAINE.

PLATE II.

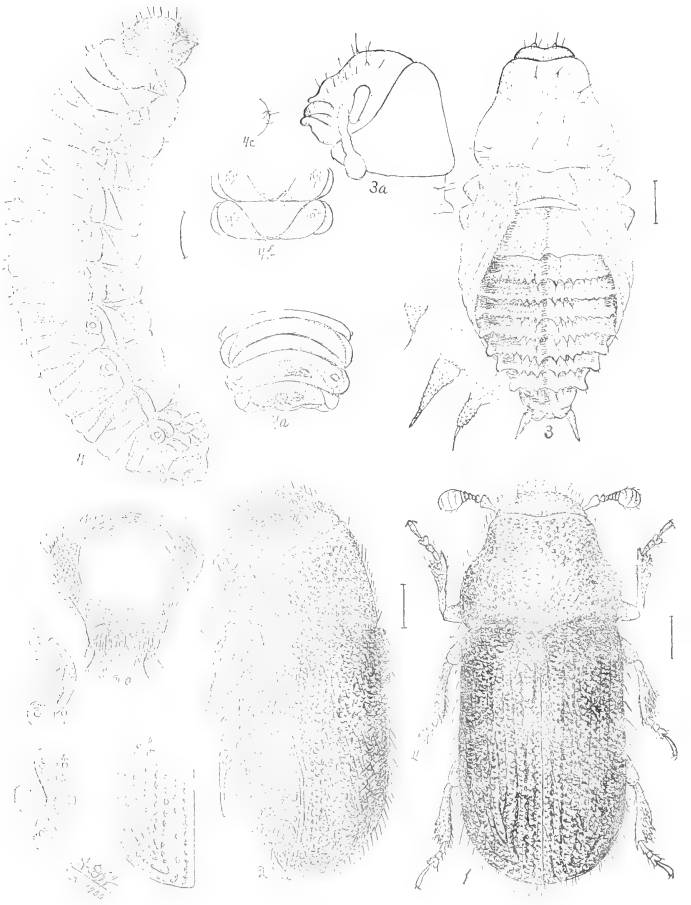
Dendroctonus piceaperda Hopk. n. sp.

1, Adult, dorsal view.

2, Adult, lateral view: *a*, Prothorax, anterior view; *b*, tip of elytron, showing arrangements of striæ, and interspaces; ♀, last abdominal segment of female, dorsal view; ♂, last abdominal segment of male.

3, Pupa: *a*, Profile of head and prothorax.

4, Larva: *a*, Dorsal plates on last abdominal segment; *b*, foot scars (?) on ventral surface of thoracic segments; *c*, profile of ventral thoracic lobe showing foot scar (?).



DENDROCTONUS PICEAPERDA HOPK., N. SP..

PLATE III.

Galleries and mines of the spruce-destroying beetle (Dendroctonus piceaperda Hopk. n. sp.)

Primary and secondary galleries or mines of the spruce-destroying beetle, showing parts of six primary galleries—reduced about one-fourth.

GALLERIES AND MINES OF THE SPRUCE-DESTROYING BEETLE.
(DENDROCTONUS PICEAPERDA, HOPK.).

PLATE IV.

Galleries and mines of Dendroctonus piceaperda in spruce.

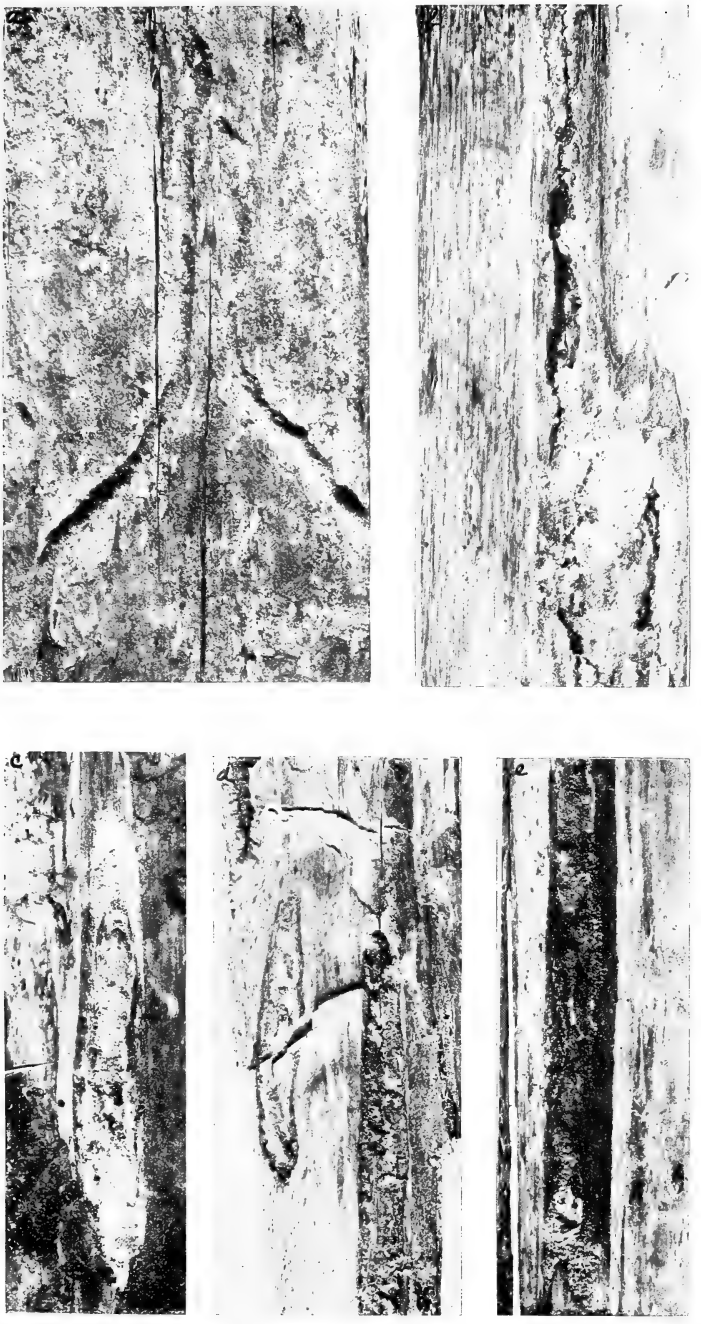
Primary and secondary galleries or mines of the spruce-destroying beetle.

GALLERIES AND MINES OF DENDROCTONUS PICEAPERDA IN SPRUCE.

PLATE V.

Old galleries of Dendroctonus piceaperda in spruce.

a, Grooves on the surface of the wood of a tree that had been dead about twelve years.
b, Wounds, or incomplete galleries, in bark of living tree; wound filled with pitch.
c, From dead tree.
d, From living tree, in which some of the wounds were healing.
e, From old dead tree, the sap wood of which was decaying.

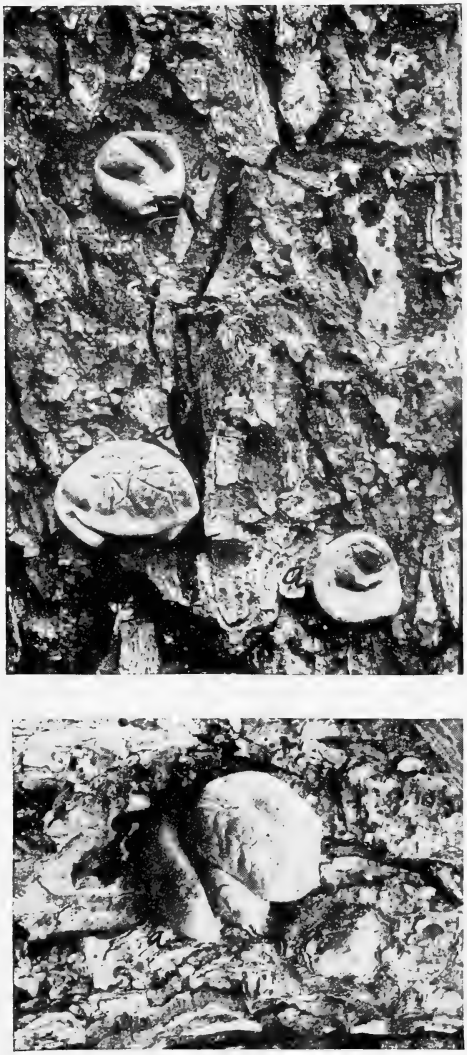


OLD GALLERIES OF DENDROCTONUS PICEAPERDA IN SPRUCE.

PLATE VI.

Spruce bark showing growth of fungus, Polyporus volvatus.

A fungus, *Polyporus volvatus* Peck, growing from holes made in the bark of trees killed by the spruce beetle—natural size.



SPRUCE BARK SHOWING GROWTH OF FUNGUS, POLYPORUS VOLVATUS.

PLATE VII.

Cocoons of Bracon simplex, a parasite of the Spruce-destroying beetle.

The cocoons of *Bracon simplex*, in the larval mines of *Dendroctonus piceaperda* are shown at *a*.

COCOONS OF BRACON SIMPLEX, A PARASITE OF THE SPRUCE-DESTROYING BEETLE.

PLATE VIII.

Work of secondary and other enemies of the spruce.

a. Work of *Tomicus picea* Hopk. MS. in white spruce bark.

b. Work of *Pityophthorus carinicepe* Lec. in spruce bark and grooving the outer wood.

c, Galleries of the destructive pine-bark beetle (*Dendroctonus frontalis*) in pine bark: also attacks spruce.

d. Work of *Dryocœtes picea* Hopk. MS on the surface of spruce wood.

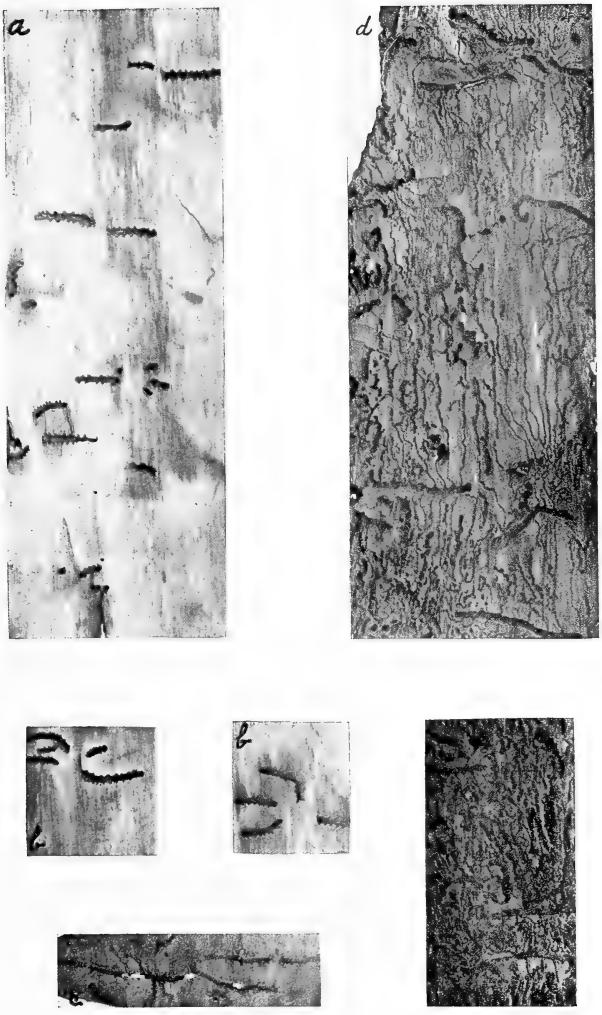
e. Galleries of the spruce Polygraphus on surface of pieces of spruce driftwood, found in Parmacheene Lake.

WORK OF SECONDARY AND OTHER ENEMIES OF SPRUCE.

PLATE IX.

Galleries of Polygraphus rufipennis showing different stages.

a, *b*, *c*, Freshly excavated galleries in living bark.
d, Old galleries in dead bark.



GALLERIES OF POLYGRAPHUS RUFIPENNIS, SHOWING DIFFERENT STAGES.

PLATE X.

Mines of Tetropium cinnamopterum.

Surface of the wood of a "peeled" and felled spruce, showing mines made by the spruce Tetropium—natural size.

MINES OF TETROPIUM CINNAMOPTERUM.

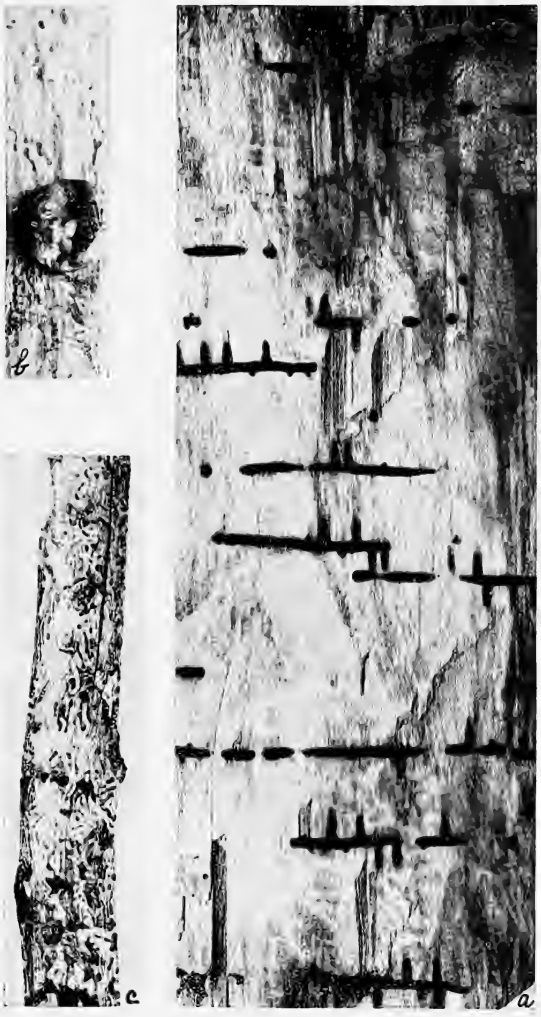
PLATE XI.

Work of Xyloterus bivittatus, and *Phlœotribus picea* Hopk. MS.

a, Work of the wood-mining beetle, *Xyloterus bivittatus*, in the sapwood of spruce—natural size.

b, Fungus (*Polyporus volvatus*) growing from mines of *Xyloterus bivittatus* on the surface of the wood after the bark had been removed—natural size.

c, Work of *Phlœotribus picea* Hopk. MS. in spruce.



WORK OF XYLOTERUS BIVITTATUS AND PHLŒOTRIBUS PICEA HOPK. M. S.

PLATE XII.

Work of Dendroctonus frontalis and Dendroctonus terebrans.

(From drawings illustrating Bulletin 56, W. Va. Agr. Exp. Station.)

a, *Dendroctonus frontalis: A*, adult; *B*, pupa; *C*, larva; *D*, adult of *Dendroctonus terebrans; E*, larva.

b, *Dendroctonus frontalis: A*, tibia; *B*, tarsus; *C*, *D*, *E*, antennæ; *F*, *G*, mouth parts. *Dendroctonus terebrans: H*, tibia; *I*, tarsus; *J*, *K*, *L*, *M*, *N*, antenna—all enlarged.

c, Pitch tube made by *Dendroctonus frontalis*—natural size.

d, Healing wounds, from living pine tree, made by *D. frontalis*—reduced.

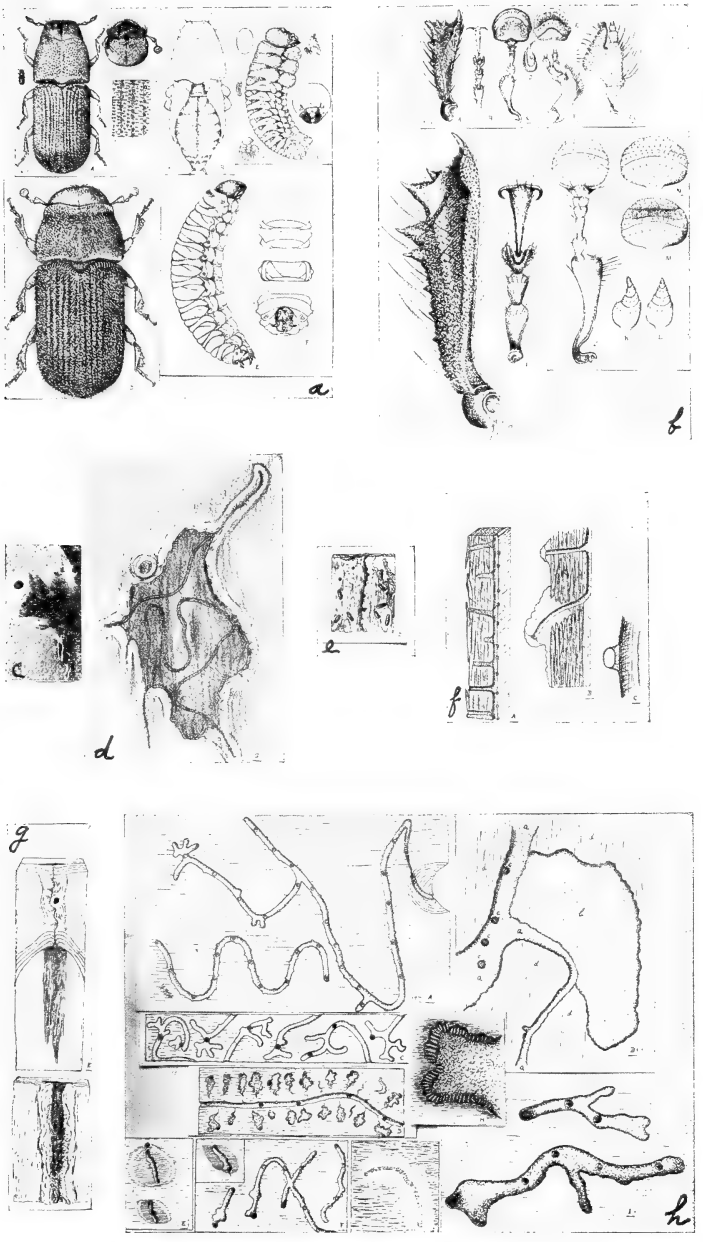
e, Pupa cases of *D. frontalis* in outer pine bark.

f, *Dendroctonus frontalis: A*, *B*, longitudinal section of primary galleries; *C*, egg in egg cavity inside of gallery—the latter enlarged; others reduced.

g, Healing wounds in living tree: *E*, *Dendroctonus frontalis; F*, *Dendroctonus terebrans.*

h, Work of *Dendroctonus frontalis* in pine bark is shown at *A*, *C*, *D*, *E*, *F*, *G;* work of *D. terebrans* in pine bark at *B*, *H*, *I;* larva at work at *H*.

NOTE.—Both *D. frontalis* and *D. terebrans* attack spruce.



WORK OF DENDROCTONUS FRONTALIS AND DENDROCTONUS TEREBRANS.

PLATE XIII.

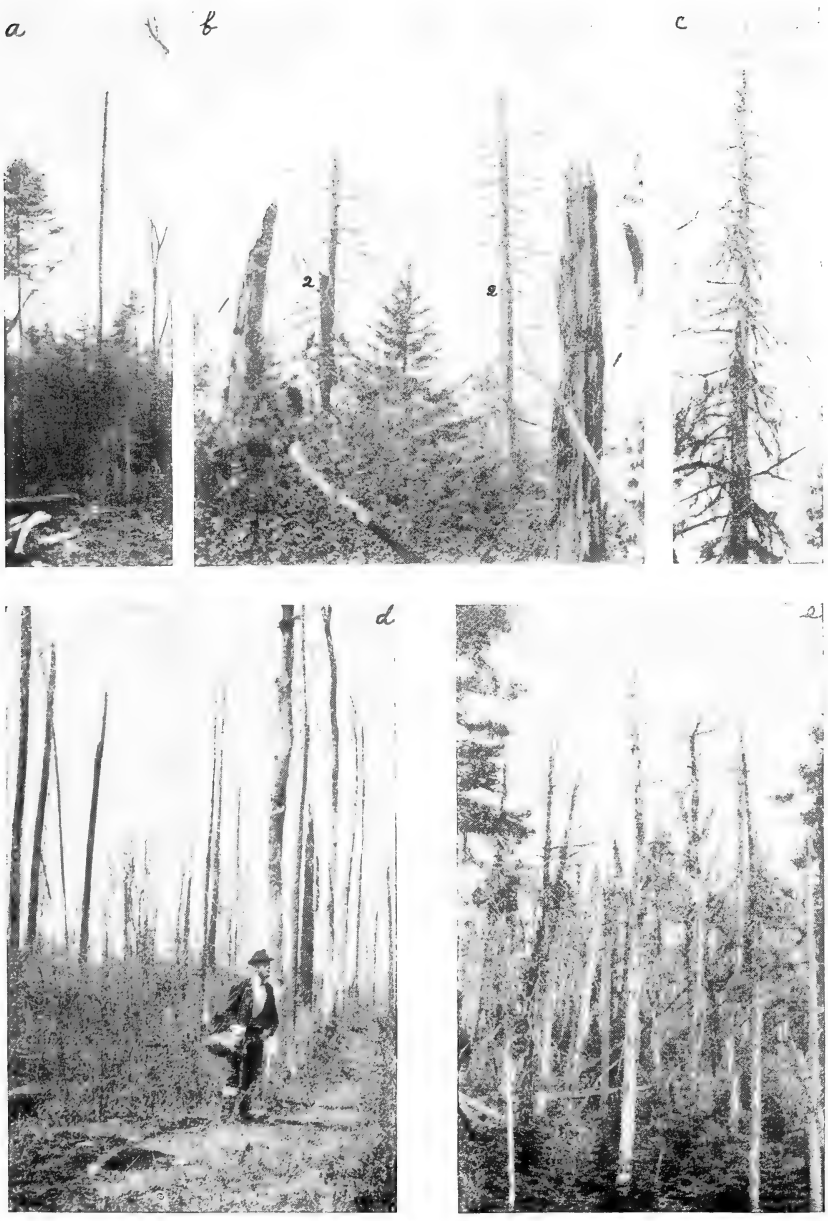
Top of Black Spruce infested with a caterpillar and a plant-louse. This shows characteristic appearance of the top and cones of the Black Spruce.

TOP OF BLACK SPRUCE INFESTED WITH A CATERPILLAR AND A PLANT LOUSE.

PLATE XIV.

Dead spruce: also fir and birch.

a, Old dead spruce and a dead birch in cutting.
b1, Remains of very old dead spruce.
b2, Appearance of spruce tree after it has been dead five to ten years or more
c, White Spruce near gamekeeper's camp, dead three or four years.
d, Dead spruce, fir, and birch, killed by fire.
e, Dead spruce and fir on summit of Rump Mountain.



DEAD SPRUCE; ALSO FIR AND BIRCH.

PLATE XV.

Timber flooded and killed by water on the Magalloway.

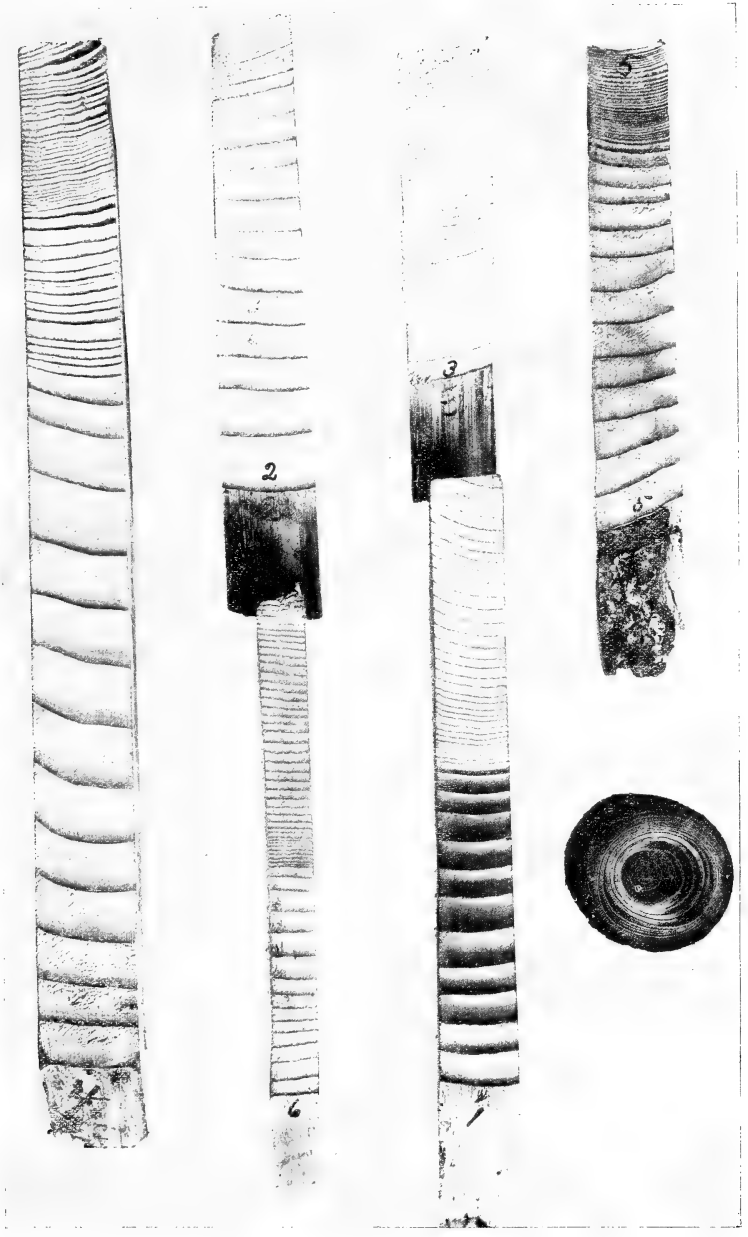
a At Camp in the Meadows.
b,c Between the dam and the camp.
c Also showing the bog spruce growing in the water.

TIMBER FLOODED AND KILLED BY WATER ON THE MAGALLOWAY.

PLATE XVI.

Sections of wood cut from Balsam Fir, showing rapid growth after the old spruces die or are felled.

1. From fir by dead tree in cutting of about 1888.
2. From fir standing by dead spruce in old cutting of about 1886.
3. From fir standing by dead tree that showed the work of the spruce beetle. Tree evidently died about 1888.
4. From fir in blow down of about 1871, which was followed by another in about 1885–86.
5. From fir in blow down of about 1886.
6. From spruce standing by large tree broken by a storm about 1886. Evidence was found in this tree that it was living when felled and that it had been attacked after falling by the spruce beetle. Both galleries and remains of beetles were found in the bark.
7. Section of small suppressed spruce about 45 or 50 years old—all natural size.



SECTIONS OF WOOD CUT FROM BALSAM FIR, SHOWING RAPID GROWTH AFTER THE OLD SPRUCES DIE OR ARE FELLED.

BULLETIN No. 28—NEW SERIES.

U. S. DEPARTMENT OF AGRICULTURE,

DIVISION OF ENTOMOLOGY.

INSECT ENEMIES OF THE SPRUCE IN THE NORTHEAST.

A POPULAR ACCOUNT OF RESULTS OF SPECIAL INVESTIGATIONS, WITH RECOMMENDATIONS FOR PREVENTING LOSSES.

PREPARED UNDER THE DIRECTION OF THE ENTOMOLOGIST

BY

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1901.

DIVISION OF ENTOMOLOGY.

Entomologist: L. O. Howard.
First Assistant Entomologist: C. L. Marlatt.
Assistant Entomologists: Th. Pergande, F. H. Chittenden, Frank Benton.
Investigators: E. A. Schwarz, D. W. Coquillett.
Assistants: R. S. Clifton, Nathan Banks, F. C. Pratt, Aug. Busck, Otto Heidemann, A. N. Caudell, J. Kotinsky.
Artist: Miss L. Sullivan.